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USSR Report

MACHINE TOOLS AND METALWORKING EQUIPMENT

No. 2

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Contents

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ROBOTICS

PROFIT DISTRIBUTION IN MACHINE BUILDING INDUSTRY DISCUSSED

Moscow FINANSY SSSR in Russian No 8, Aug 82 pp 17-26

[Article by G. V. Bazarova, deputy chief of the Scientific Research Institute of Finance, and O. V. Repina, chief of the Machine Building Financing Administration of the USSR Ministry of Finance: "The Standard Method of the Distribution of the Profit"]

[Text] In the set of measures on improving planning and strengthening the influence of the economic mechanism on increasing production efficiency and work quality, which are stipulated in the decree of the CPSU Central Committee and the USSR Council of Ministers of 12 July 1979, an important place is assigned to the standard method of the distribution of the profit.

It is envisaged to establish beginning with the 11th Five-Year Plan for industrial ministries, as they become ready, on the basis of the assignments approved in the five-year plan stable standards of deductions from the profit (with a differentiation by years), which are placed at their disposal. The portion of the profit, which is left in accordance with the standard, is intended for the financing of capital investments, the repayment of bank credits and the payment of interest, the assurance of the increase of internal working capital, the formation of a unified fund for the development of science and technology and economic stimulation funds, as well as the meeting of other planned expenditures on the development of the sector.

The ministries are permitted to establish on the basis of the amount of profit, which is left at their disposal, and with allowance made for the peculiarities of production and the level of profitability the corresponding standards of the deductions from the profit for industrial associations, as well as production associations and large enterprises. As the necessary conditions are created and experience is gained, they should be established for all production associations (enterprises).

The changeover from the procedure of distributing the profit, which was in effect until now, to the standard method is being carried out for the purpose of increasing the economic liability of ministries, associations and enterprises for the results of financial and economic activity and increasing their interest in the most efficient use of material, manpower and financial resources.

The absolute amount of the contributions from the profit to the state budget and, as required, the allocations from the burget are approved in conformity with the standard in the five-year plans (with a breakdown by years). In the case of the nonfulfillment in some year of the five-year plan of the approved plan of the profit the payments to the budget, which are stipulated in the five-year plan for that year, are made in full by means of the corresponding decrease of the profit which is left at the disposal of the ministry. In turn, in the case of the drafting by the ministries of annual plans which exceed the assignments of the five-year plan for the corresponding year, a portion of the additional profit in accordance with the approved standard is left at their disposal. In the case of the exceeding of the annual plans 50 percent of the above-plan profit is left at the disposal of the ministry (association, enterprise). In the case of the exceeding of the plan of the profit by more than 3 percent, 25 percent of the amount of the excess is left at its disposal. The remainder of the above-plan profit is to be paid into the state budget. Here the incentive markups on the wholesale prices for efficiency and quality are taken into account and distributed separately.

When elaborating the standard method of distributing the profit the experience of its use, which had been gained by a number of industrial ministries, first of all the Ministry of Instrument Making, Automation Equipment and Control Systems, as well as the Ministry of Heavy and Transport Machine Building, the Ministry of Power Machine Building and the Ministry of Tractor and Agricultural Machine Building, was used extensively. In 1980-1981 the Ministry of the Electrical Equipment Industry, the Ministry of Construction, Road and Municipal Machine Building, the Ministry of Machine Building for Animal Husbandry and Fodder Production, the ministries of the meat and dairy and the food industry of individual union republics, as well as the State Committee for Publishing Houses, Printing Plants and the Book Trade changed over to the standard method. It has been used for a number of years in the Main Administration of Motor Transport of the Moscow City Soviet Executive Committee and the motor transport managements of a number of union republics, as well as in three republic construction ministries--the Belorussian SSR Ministry of Industry Construction and Ministry of Installation and Special Construction Work and the Ukrainian SSR Ministry of Construction of Heavy Industry Enterprises.

As a whole it should be noted that the changeover to the new method is being carried out slowly, many ministries have postponed the planned date, giving as a reason for the delay the expectation of new wholesale prices. On 1 January 1982 new wholesale prices and rates were introduced, but the scope of the use of the method for the present remains as before. The actual causes of the formed situation lie, of course, deeper. They are connected with the considerably greater inflexibility of this method as compared with the old method and the difficulties of realizing its advantages under the specific economic conditions of the fulfillment of the plan of the 11th Five-Year Plan. These causes will become clearer as a result of the analysis of the experience of using the standard method, which has already been gained.

The Ministry of Instrument Making, Automation Equipment and Control Systems was first among the industrial ministries to begin using this method back in July 1970 and at the same time implemented other measures aimed at the enhancement of the role of the five-year plan and the strengthening of economic methods in the management of the sector. At the same time the system used in the Ministry of Instrument Making, Automation Equipment and Control Systems had several differences from the

one envisaged later by Decree No 695 of the CPSU Central Committee and the USSR Council of Ministers. Thus, in particular, the distribution of the above-plan profit was carried out according to the same standard as the planned profit, the saving and the overexpenditures on the fee for capital as compared with its planned amount were not reflected in the amounts of the actual profit left at the disposal of the ministry. The mandatory reporting of the standard method of distributing the profit to all subordinate production associations and enterprises was not stipulated, a centralized procedure of settlements with the state budget on payments from the profit was used. All this limited the effect of the new system on the efficiency of the activity of the enterprises of the sector.

As a whole the more than 10 years of practical experience of using the new system showed that the Ministry of Instrument Making, Automation Equipment and Control Systems had successfully coped with the plan assignments and had achieved higher growth rates of many indicators as compared with other machine building ministries and the average data for the sector of civil machine building, especially during the years of the 9th Five-Year Plan. Thus, during 1971-1975 the increase of the production volume in the Ministry of Instrument Making, Automation Equipment and Control Systems came to 223.9 percent as against 220.7 percent in accordance with the five-year plan with an average indicator as a whole for the machine building sectors of 163.2 percent. The average annual increase of the production volume came to 17.5 percent as against 10.3 percent for machine building. The output of cultural, personal and household items increased by 2.2-fold, including the output of jewelry by 2.9-fold and timepieces of all types by 1.9-fold. The increase of labor productivity came to 182.2 percent as against 182 percent in accordance with the five-year plan, while on the average for machine building it came to 146.2 percent.

During 1971-1975 the increase of the profit came to 419 percent as against 365 percent, which was envisaged by the five-year plan. The production cost of industrial output decreased by 15.6 percent with 8.4 percent for machine building as a whole. According to the results of the work during the period in question the ministry derived from all types of activity an above-plan profit in the amount of 191.2 million rubles, of which 50.8 million rubles were channeled into the state budget.

The following data attest to the proportion of the enterprises of this sector, which fulfilled and exceeded during the years of the 9th Five-Year Plan the plan assignments on the basic economic indicators (percent of the total number of enterprises according to the report for 1975):

	Ministry of Instrument Making, Automation Equipment and Control Systems	On the average for machine building
Volume of output.	99.5	93.5
Labor productivity.	92.0	86.9
Profit.	98.7	86.4

During the 10th Five-Year Plan in the Ministry of Instrument Making, Automation Equipment and Control Systems leading growth rates for production, labor productivity, the profit and other indicators were maintained as compared with the other machine building ministries, although in the five-year plan itself in connection with

the decrease of the rate of increase of raw materials and manpower resources and other factors the assignments on the indicated indicators were set lower than for the 9th Five-Year Plan. As a whole during the 10th Five-Year Plan the growth rate of industrial production for the ministry came to 160.6 percent, labor productivity--152 percent and the profit--229.3 percent as against the assignments according to the total of the annual plans of respectively 153.5 percent, 149.1 percent and 223.5 percent. Here the assignments of the five-year plan were not fulfilled with respect to the increase of production and the profit.

During those years the Ministry of Instrument Making, Automation Equipment and Control Systems achieved a decrease of the production cost in the amount of 10.8 percent. This is slightly less than the annual assignments (11.7 percent), but considerably more than on the average for machine building (3.3 percent). In this ministry the indicators of the output-capital ratio and the use of equipment are also higher than in a number of others.

The changeover of ministries to cost accounting methods of activity and the standard method of distributing the profit as a whole had a positive effect on the indicators of the fulfillment of the plan on capital construction. The plan on the amount of capital investments as a whole during the 10th Five-Year Plan was fulfilled by approximately 101 percent. A substantial change was outlined in the direction of the decrease of the amount of unfinished construction work, the amount of which in 1978 and 1979 was less than the standard (67 percent). The improvement of the indicator of the fulfillment of the plan on the placement of fixed capital into operation was less stable: appreciable positive changes were achieved only in 1978 and 1979. However, the change of just the sources of financing and the methods of distributing the profit in a client sector can hardly have a decisive influence on the increase of the effectiveness of capital investments as a whole, which to a considerable extent is determined by the availability of capacities and the organization of the work among the contractors which worked in the old way during the period being analyzed.

During all the years of the work under the new conditions the Ministry of Instrument Making, Automation Equipment and Control Systems ensured the fulfillment of the set plans on the profit and the payments to the budget. As a whole during 1971-1979 the assignments on the profit were fulfilled by 103.5 percent and on the payments to the budget by 101.9 percent. During this period an above-plan profit of 344 million rubles was derived for all types of activity, of which 124 million rubles were paid to the budget and 220 million rubles were left at the disposal of the ministry.

The results of the experiment conducted in the Ministry of Instrument Making, Automation Equipment and Control Systems attest to the high level of economic work in the sector. Serious preparation for the changeover to cost accounting methods of activity was carried out here. This found expression first of all in the strengthening of the economic services, the implementation of measures on the elimination of the bottlenecks in the work of individual enterprises and the creation in each subsector of a council of directors for the preparation of specific proposals on the improvement of production operations. An automated system of calculations (the ASU-pribor), which ensures the obtaining in 2-3 days after the period under review of data, which are used for monitoring and the taking of steps on the fulfillment by enterprises of the plan assignments on the sale of products, the profit, labor productivity, the production of consumer goods and other indicators, is being used

extensively in the sector. It is well known that in other sectors the indicated information is received later, which limits the real possibilities for the elimination of the allowed shortcomings and the making up of the losses.

At the same time the analysis of the results of the experiment in the Ministry of Instrument Making, Automation Equipment and Control Systems attests to the existence of certain shortcomings, which are due to both external causes (the instability of the plan assignments, the annual revision of wholesale prices, the shortcomings of material and technical supply) and causes which depend on the ministry. Thus, the tendency for the share of the indicator of the decrease of the production cost in the increase of the profit to decrease has been observed. Whereas in 1976 the increase of the profit due to the decrease of the production cost came to 47.8 percent, in 1980 it came to 26.7 percent. Along with such causes as the decrease of the growth rate of production and the increase of the output of more complicated products this was also due to above-plan losses from defective production, unproductive expenditures and losses in connection with shortcomings in the organization of production and labor.

During the 10th Five-Year Plan the ministry implemented measures on the increase of the output of products of the highest quality category. Whereas in 1975 their proportion in the total production volume came to 8.5 percent, by 1980 it had increased to 42.5 percent. However, serious shortcomings exist in the work on increasing product quality. Thus, in 1979 more complaints against items with the Seal of Quality were received than in 1978; their number for personal timepieces of all types increased.

The associations and enterprises of the ministry are annually increasing the output of machines and instruments of all types. At the same time the effectiveness of the measures on new equipment as compared with the expenditures on its production decreased during the 10th Five-Year Plan. This attests that inadequate attention is still being devoted to the choice and the implementation of effective measures on new equipment and the obtaining of a return on invested capital in a shorter period.

The need for the thorough reorganization of all the economic work, the style and methods of management in conformity with the new requirements is convincingly confirmed by the analysis of the experience of the work of the ministries (the Ministry of Tractor and Agricultural Machine Building, the Ministry of Heavy and Transport Machine Building and the Ministry of Power Machine Building), which were changed over to the standard method of distributing the profit later on, in 1977-1979. By the time of the changeover they had some experience in the use of the new methods of management--the cost accounting system of the organization of work on new equipment was adopted here (first of all in the Ministry of Heavy and Transport Machine Building, where it began to be used in 1972).

Under the condition of the implementation of a more extensive set of measures on the improvement of the methods of management in these sectors, as a rule, sufficiently high growth rates of the production volumes and labor productivity were ensured and the proportion of products of the highest quality category increased considerably. For example, in the Ministry of Tractor and Agricultural Machine Building the growth rate of the production volume according to the report for 1976-1980 came to 130 percent, labor productivity--127.3 percent; the number of measures on

new equipment increased by 2.2-fold, the additional profit from their introduction increased by 38.5 percent, the annual economic impact per ruble of production expenditures increased by 35.3 percent. In the Ministry of Heavy and Transport Machine Building the production volume (in the new measurer of the standard net output) during the years of the 10th Five-Year Plan increased by 22.4 percent, the output of cultural, personal and household goods increased by 53.5 percent. Labor productivity, which was calculated according to the standard net output, increased by 21.1 percent. The plan assignments on the increase of labor productivity (which were made more precise) were fulfilled by the majority of enterprises; in 1980 98.5 percent of the increase of the produced output was obtained due to this factor. The expenditure of wages per ruble of net output for the sector as a whole decreased by 5.2 percent. Much was done to improve the quality and increase the technical level of the machines and equipment being produced. The proportion of the products of the highest quality category increased by more than twofold as compared with the 9th Five-Year Plan and came to 31.3 percent.

In the Ministry of Power Machine Building during 1976-1980 the production volume increased by 27.2 percent, labor productivity--9 percent, the number of implemented measures on new equipment--2.5-fold, the number of workers conditionally released per year as a result of this--fourfold.

At the same time the growth rates of the production volume and labor productivity in these ministries during the 10th Five-Year Plan were lower than the assignments of the five-year plan, while in individual years they were lower than the assignments of the refined annual plans.

The fulfillment of the plan of the profit was not achieved in any of the three ministries; its growth rate in the Ministry of Heavy and Transport Machine Building and the Ministry of Power Machine Building was less than the indicators of the adjusted plans. In the Ministry of Power Machine Building instead of a decrease of the production cost as a whole during the five-year plan by 2.96 percent its increase in the amount of 1.13 percent was permitted. In the Ministry of Heavy and Transport Machine Building with a planned increase of this indicator by 0.31 percent the actual increase came to 0.97 percent. The formed situation to a certain extent was the result of the influence of objective factors. However, it is impossible not to note that the influence of the new methods here for the present has still not been fully revealed. The ministries did not display adequate persistence in the implementation at subordinate enterprises of measures on the tightening up of planning and financial discipline and the improvement of the style and methods of management on the basis of the new principles of management. At the enterprises large overexpenditures of ferrous and nonferrous metals, as well as other material resources are being permitted, the unproductive expenditures and losses remain significant, the introduction of new types of products is being delayed for a long time.

In contrast to the Ministry of Instrument Making, Automation Equipment and Control Systems, during the changeover of these ministries to the new methods of management in connection with the lower level of their profitability and the considerable amounts of capital investments the budget financing of capital investments in a specific fraction of the amount of expenditures on new construction was retained for them (in the Ministry of Tractor and Agricultural Machine Building and the Ministry of Heavy and Transport Machine Building up to 30 percent, in the Ministry of

Power Machine Building up to 70 percent). Here it was intended that as the expenditures decreased and the profitability increased the budget allocations would be replaced by internal sources of financing. However, the ministries were not able to ensure such a replacement of resources. Moreover, as a result of the inadequate mobilization of internal economic resources assistance was repeatedly given to them through the state budget for the financing of a number of expenditures (for the repayment of bank credits, which were issued for the increase of the standards of internal working capital, the increase of the unified fund for the development of science and technology, the paying off of the debt in capital construction, additional capital investments). In this connection the principle of the planned payments from the profit, which were guaranteed to the budget, was not always observed.

The analysis of the causes of the incomplete influence of the standard method of distributing the profit and other principles of cost accounting management on the results of the activity of the indicated sectors makes it possible to distinguish the influence of both objective negative factors, which are "external" with respect to each individual sector and at the same time are common to all of them, and subjective factors, which are connected with the level of management and the scale of the use of the new methods of management.

1. During the period of the use of the standard method of distributing the profit in the indicated sectors it was not possible to see to it that a stable five-year plan with a breakdown of the assignments by years became the basis of the planning of their financial and economic activity, as is stipulated by the new methods of management. During the 9th and 10th Five-Year Plans the necessary balance of the physical and value indicators of the plan was not achieved. It is impossible not to consider that a few of the sectors, which had been changed over to the new principles of management, were only "islets" in the system of sectors, associations and enterprises, which managed in the old way and with which they were connected by an extensive network of reciprocal deliveries and obligations. The Ministry of Heavy and Transport Machine Building, for example, during the 10th Five-Year Plan received 9 percent less rolled products than the plan, 17 percent less casting sand and 23 percent less of several special makes of steel.* In connection with the instability of material and technical supply and the changes of the amounts of capital investments and wholesale prices the indicators of the financial plans and the standards of the distribution of the profit underwent repeated adjustments. The following data of the Ministry of Instrument Making, Automation Equipment and Control Systems, in particular, attest to this (see the table).

As is evident from the cited data, during the 10th Five-Year Plan standards were approved only for the indicators of the annual plans. All this weakened the interest of the ministries in the drafting of stepped-up plans and limited the sphere of effect of the standard, in essence, just to the framework of the above-plan profit for the corresponding year.

2. The scale of the influence of the new methods of management on the increase of production efficiency and the mobilization of internal reserves was also limited due to the influence of a number of factors which depend on the ministries themselves, on the level of their economic work, and first of all due to the slow reporting of the standard method to the basic unit of management--the production

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*PRAVDA, 15 February 1982, p 2.

associations and enterprises. In this connection industry, in reality, does not have adequate experience in the use of these standards at the level of the basic unit. Only during the second half of 1980, that is, during the 10th year of the use of the new methods, did the Ministry of Instrument Making, Automation Equipment and Control Systems change over as an experiment to the standard procedure of distributing the profit nine subordinate associations and enterprises and only in 1982 is it planning to change over the others. The Ministry of Heavy and Transport Machine Building has changed over 45 enterprises, the Ministry of Tractor and Agricultural Machine Building initially changed over 13 (in 1980) and only in 1980 did it change over the others.

Standards of the Deductions From the Profit for Disposal by the Ministry of Instrument Making, Automation Equipment and Control Systems During the Years of the 9th and 10th Five-Year Plans (percent)

	9th Five-Year Plan					10th Five-Year Plan				
	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Approved for indicators of five-year plan. . . .	54.0	47.8	44.6	37.8	32.6	X	X	X	X	X
Refined for indicators of annual plans in connection with change of prices and conditions .	54.0	49.1	62.7	52.6	54.6	45.80	43.17	39.96	33.68	41.07
Were actually in effect. . . .	54.0	49.1	63.2	51.2	55.7	57.06	43.26	42.55	41.36	43.79

One of the basic causes of the incomplete return of the new methods lies in this. In explaining the causes of the formed situation, the ministries cited the instability of the plan assignments, shortcomings of material and technical supply and other factors, which hinder the stable operation of enterprises. Meanwhile the overcoming of these difficulties to a considerable extent also depends on the ministries themselves, on the level of their planning, economic and organizing work.

The survey conducted by financial organs of 32 production associations and enterprises, which had been changed over to the standard method of distributing the profit and the new conditions of determining the fee for capital, showed that the results achieved by them in 1980 and in 9 months of 1981 were higher than as a whole for the ministries which use the new methods of management. The comparative data on the growth rate of the commodity and standard net output, the placement of production capacities and facilities into operation, the output-capital ratio, the profitability, the profit and the payments to the budget attest to this. Thus, the checked associations and enterprises fulfilled the plan of the profit during 1980 as a whole by 99.6 percent and in 9 months of 1981 by 100.6 percent. In all 7 enterprises (21.8 percent of the total number) did not fulfill the plan of the profit in 1980 and 6 enterprises (18.7 percent) did not fulfill it in 9 months of 1981.

The plan of payments from the profit to the budget was fulfilled as a whole for these enterprises in 1980 by 100.1 percent, while in 9 months of 1981 it was fulfilled by 102.5 percent. Here respectively seven enterprises and one enterprise

did not cope with the plan assignments. The level of the fulfillment of the plan of the profit and the payments to the budget as a whole for a number of ministries, which had been changed over to the new conditions of management, during the period in question was lower. Of course, in the case of such a comparison it is impossible not to consider that the enterprises, which work most stably, as a rule, were the first to be changed over to the standard method of distributing the profit.

However, as the results of the check attest, the influence of the standard method of distributing the profit was limited due to a number of shortcomings in the practice of approving and using this economic standard. At the time of the check (December 1981) the indicated standards had been approved by only 12 associations and enterprises of the 32 checked ones (here 4 approved them only in April-May 1981). For the remaining enterprises the standards were specified by estimation, on the basis of the indicators of the annual financial plans.

The approved standards were repeatedly changed during the year as a result of the change of the plan of the profit and the payments to the budget, in connection with which the actually used standards, as a rule, did not conform to the established standards. For example, the standards of the deductions from the profit were approved for the Vilnius Plant of Fuel Equipment imeni 50-letiya SSSR for 1980 in the amount of 80.5 percent and for 1981 in the amount of 81.62 percent. In 1980 the distribution of the profit was changed four times for the association and in 9 months of 1981 also four times. As a result during those years the standards came to 85.46 and 80.35 percent.

At several associations and enterprises, which had been changed over to the standard method, the amount of the profit left at their disposal did not always correspond to the established standard. For example, the profit left at the disposal of the Khar'kovskiy traktornyy zavod Production Association according to the plan for 1980 was understated as against the standard by 2.4 million rubles and for 1981 by 2.5 million rubles. According to the data for 9 months of 1981, the amount of the profit, which was left at its disposal, was overstated as against the standard by 1.7 million rubles. This means that the standard established for the association in fact was not used when distributing the profit.

The noted shortcomings attest both to the objective difficulties of maintaining the stability of the standards in the basic unit as a result of the imbalance of the plans and other factors and to the formal approach to the changeover to the new methods and the direct failure in a number of instances to observe the established principles.

The standard method in the basic unit is, in essence, only at the stage of formation. Under these conditions, in our opinion, it is especially important to study carefully the available experience, in order to eliminate the shortcomings in good time and to provide normal conditions for the use of the standards in the mechanism of the distribution of the planned and above-plan profit. Thus, the first results of the use of the standard method have already shown that a portion of the checked enterprises experienced a shortage of the above-plan profit for the payment of bonuses in accordance with the All-Union Socialist Competition. The study of this question led to the conclusion that it is expedient to make some refinements in the used procedure of its standard distribution. Prior to the changeover to the new methods the enterprises and associations were permitted in case of a shortage

of the above-plan profit and other sources to cover the missing portion of the assets by means of the net surplus of the profit, which is to be paid to the state budget in accordance with the plan. Under the new conditions they could make these payments only within the limits of the above-plan profit left to them in accordance with the standard.

With allowance made for the importance of the development of socialist competition and the provision of normal conditions for the material stimulation of the winners in a special letter of the USSR Ministry of Finance it was stipulated that the payment of bonuses in accordance with its results under the conditions of the standard method of distributing the profit is carried out before the distribution of the above-plan profit in accordance with the standard. Such a procedure provides a more reliable financial source for the payment of bonuses. At the same time under these conditions the share of enterprises, associations and ministries in the distribution of the above-plan profit is being increased accordingly.

The analysis of this special, although important, question also leads, however, to broader conclusions. The expediency of the further preservation under the current conditions of management of the very practice of stimulating the winners of the socialist competition entirely or primarily at the expense of the above-plan profit raises doubt. Such a procedure hardly conforms to the tasks of the improvement of planning, the enhancement of the role of the five-year plan in the management of the economy and the elaboration of stepped-up plan assignments. On the contrary, it more likely prompts enterprises and associations to conceal reserves in the process of planning for the purpose of providing assets for the payment of these bonuses. The existing procedure of reimbursing a large number of other expenses, of which up to now the above-plan profit has served as the source, also has the same influence. Therefore, in our opinion, it would be advisable to implement in the future measures which are aimed at some "relieving" of the above-plan profit. In particular, it is possible to achieve this by the payment of bonuses to the winners of the socialist competition at the expense of the assets of the centralized material incentive funds, which are now being created at all-union industrial associations, and the reserves of ministries with respect to these funds.

A different procedure than at present of offsetting the above-plan losses from the operation of housing and municipal services, in our opinion, would also contribute to the solution of the problem in question. Instead of offsetting these losses at the expense of the above-plan profit it is economically sounder to cover them by means of the fund for sociocultural measures and housing construction of associations and enterprises.

In the process of using the standard method of distributing the profit at the level of production associations and enterprises other methodological questions, the timely settlement of which will make it possible to increase the influence of financial levers on production efficiency, may also arise. Thus, with the changeover to the new method the conditions are created for the implementation of the measures on the increase of the influence of the fee for assets on the use of productive capital, which are stipulated by Decree No 695 of the CPSU Central Committee and the USSR Council of Ministers. A procedure, in conformity with which the fee for above-standard stocks of physical assets, for which credit has not been extended, and uninstalled equipment is paid to the budget at the expense of the profit left at the disposal of enterprises, is being put into effect. In turn, the saving on

this payment, which was achieved on the condition of the fulfillment of the plans of production and the profit with a smaller value of the assets than stipulated in the plan, is left at the disposal of the associations and enterprises and the payments to the state budget are reduced by this amount.

The study of the effectiveness of the new procedure of the fee for assets using the experience of 32 associations and enterprises under the conditions of the standard method of distributing the profit showed that at a number of enterprises a significant decrease of the amounts of the above-standard surpluses of commodity stocks and uninstalled equipment was achieved with its introduction. Thus, at the Kurgansel'mash Plant of Agricultural Machine Building of the Ministry of Machine Building for Animal Husbandry and Fodder Production the above-standard reserves of commodity stocks, for which credit had not been extended by the bank, on 1 January 1980 came to 1,161,000 rubles, while by 1 October 1981 their amount had been decreased to 94,000 rubles. At the Sigma Production Association of Computer Equipment the above-standard stocks of materials, for which credit had not been extended by the bank, in 1980 were decreased as compared with 1979 by 73,000 rubles, while as of 1 October 1981 they did not exist. At the Mogilev Strommashina Plant imeni 50-letiya Velikogo Oktyabrya as a result of the performed work the above-standard surpluses were decreased in 1981 by 288,000 rubles, including those worth 98,000 rubles, which were sold in accordance with the orders of an administration of the Belorussian SSR State Committee for Material and Technical Supply, and those worth 190,000 rubles, which were committed to production. As of 1 October 1981 there were no above-standard surpluses, for which credit had been extended by the bank, at the enterprise.

At the same time at many enterprises the stimulating influence of the new procedure of using the fee for assets was not properly revealed. The saving on the fee for assets was obtained at only four enterprises among those checked.

For the purpose of increasing the effectiveness of the fee for assets as an economic lever under the conditions of the standard method of distributing the profit it would be advisable, in our opinion, to strengthen the link of the fee with the material interests of the production collectives. It is possible to achieve this, for example, by the direct transfer of a portion of the obtained saving on this payment to the material incentive fund and accordingly by the offsetting by means of the assets of this fund of a portion of the overexpenditure on the fee for assets. At present the overexpenditure on the fee for assets has only an indirect influence on the incentive funds, since it decreases the above-plan profit and thereby limits the source of additional contributions to the incentive funds. The establishment of a direct dependence between the fee and the funds will increase its stimulating role.

The proper organization of the settlements on payments from the profit to the budget is of considerable importance for the realization of the advantages of the standard method of distributing the profit. The procedure of settlements should prompt enterprises to the timely and complete meeting of their obligations to the budget and should ensure the control of financial organs over the results of their activity. The instructions of the USSR Ministry of Finance on this question* envisage

*Instructions on the Procedure of Settlements With the State Budget on Payments From the Profit of Ministries, All-Union (Republic) Industrial Associations, Production Associations and Enterprises, Which Have Been Changed Over to the Standard Method of the Distribution of the Profit. Approved by the USSR Ministry of Finance on 12 October 1979.

the use under the conditions of the standard method of a decentralized procedure of settlements. However, some economists have expressed the opinion that a different approach to this question is needed. A portion of the machine building ministries, first of all the Ministry of Instrument Making, Automation Equipment and Control Systems, on the basis of their experience of work are also insisting on the use in the future of only the decentralized procedure of settlements with the budget. Here in the case of the changeover of all enterprises to the standard method it is presumed that they would make settlements in accordance with the standards established for them not with the budget, but with the ministry.

The stand of the Ministry of Instrument Making, Automation Equipment and Control Systems on this question, in our opinion, can hardly be deemed correct, since it leads to the weakening of cost accounting. When making settlements in accordance with the consolidated balance the poor work of other enterprises is covered at the expense of enterprises which work well, and this is at variance with the principles of cost accounting, although it makes the observance of the guaranteed payments easier for the sector.

Since the standard method of distributing the profit in the future will be used at the level of production associations and enterprises, we believe that under these conditions the settlements on deductions from the profit should be made in a decentralized manner, that is, on the basis of the direct relations of enterprises with the budget. Such a procedure increases the responsibility of each enterprise and association for the results of the financial and economic activity, the timeliness and completeness of the settlements with the budget on the payments from the profit and provides the conditions for the establishment of the more effective control of local financial organs over their activity. At present the first steps have been taken in this direction. Starting in 1981 decentralized settlements on the fee for assets were introduced for seven machine building ministries which had been changed over to cost accounting methods of activity. Along with this all the enterprises of the Ministry of Machine Building for Animal Husbandry and Fodder Production since 1981 have been making settlements with the budget in a decentralized manner both on the fee for assets and on the deductions from the profit. The other six machine building ministries for the present are making settlements with the budget on the deductions from the profit in a centralized manner, in accordance with the consolidated balance. Such a procedure is permissible as a temporary measure, by way of adaptation of the new method to the real conditions of management.

In conclusion it should be noted that the standard method, although important, is all the same only one of the many components of the new economic mechanism. The complete implementation of the entire set of measures on the improvement of planning, the improvement of capital construction and the development of cost accounting, which are stipulated by the decree of the CPSU Central Committee and the USSR Council of Ministers of 12 July 1979 and the decisions of the 26th CPSU Congress, is a decisive condition of its effective use.

More favorable conditions for the broadening of the sphere of use of this method are already being created this year. The formulation of economically sound standards of working capital for industrial ministries has been completed, new wholesale prices and rates have been introduced and the conversion of the plan indicators into the new prices is being completed. Therefore in 1982-1983 it is expedient to increase accordingly the number of industrial ministries, associations and enterprises, which are being changed over to the new methods of management.

With allowance made for the refinements examined above it would be possible to extend the standard method also to the enterprises of individual highly profitable sectors of agriculture, particularly poultry-raising sovkhozes, to envisage its more extensive use in transportation and to complete the changeover of the enterprises of motor transport in all the union republics to the new methods of management. With the revision of the estimated prices and the strengthening of the new principles of management in construction it is expedient to broaden the sphere of application of the new method in this sector of the national economy as well, relying on the experience gained by individual union republics in its use during the 10th Five-Year Plan.

The implementation of these measures will contribute to the increase of production efficiency and work quality.

7807
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COLLOCATION OF PLANTS, NATURAL RESOURCES, MARKETS DISCUSSED

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[Article by A. Tselikov, USSR Academy of Sciences academician, general director of the "VNII metmash" [All-Union Scientific Research and Planning Design Institute of Metallurgical Machine Building] NPO [Scientific Production Association]

[Text] The vast expanse of the territory of the USSR with its nonuniform distribution of natural resources and various climatic conditions, demands an especially extensive analysis of the locations of enterprises. The basic guiding principle in this is the compatibility of purpose and size of the enterprise, and the natural and labor resources of the given region. Only by observing the indicated principles can production become profitable for the country, as well as for the region. The nature of this compatibility depends greatly on specialization; it is more defined with respect to production enterprises that utilize the natural resources of the region, but it is more complex for machine building enterprises. For example, it is most expedient to build hydroelectric power plants where there are the necessary hydraulic power resources. If there is also a need for power, the problem may be considered to be solved.

Criteria for Disposition of Metallurgical Enterprises

The optimal locations of a ferrous metallurgy plant may also be clarified on the basis of definite economic criteria. To obtain a ton of steel, several tons of raw materials must be used of which iron ore is the main one. The richest ores contain no more than 60 to 65% iron, while the iron content, taking into account the use of enriched ores, was about 54% in 1981.

The weight of coal or coke consumption is, on the average, half the weight of the cast iron produced, i.e., unit transportation costs per kilometer to deliver fuel are lower than for ore. It follows from this that to reduce transportation costs, it is more advantageous to locate ferrous metallurgy enterprises closer to ore deposits.

In the case where metallurgical production operates on scrap, it is more efficient to locate it in regions where scrap originates or where there are consumers of the product manufactured by the enterprise. Thus, it is more advantageous to organize the manufacture of gas and petroleum pipe closer to routes of the pipelines, rather than to the producers of the initial metal for the pipe. These pipes have basically

thin walls; the ratio of their thickness to their diameter is 1:100 to 1:60. This means that loading them in a RR car does not fully utilize the load capacity of the car. From this standpoint, plants for manufacturing welded 720to 1420 mm diameter gas and petroleum pipe from sheet rolled stock should have been located not in Khartsyask and Volzhsk, but in northern regions of the country and Siberia, i.e., closer to the places where they are used.

Plants that produce primary aluminum may serve as another example of a solution solution of the problem of locating a metallurgical enterprise. The technology of its production is based on the electrolysis of molten bauxites and requires considerable electrical power consumption -- on the average of about 17,000 kw-hours per ton of aluminum, i.e., about 35 times more than for melting steel in electrical furnaces. Transportation costs for raw material -- bauxites -- are considerably lower than the cost of electrical power. Therefore, aluminum plants should be located where the cost of electric power is the lowest. Thus, building three large aluminum plants in Irkutsk, Bratsk and Krasnoyarsk, using the power resources created there, was well substantiated.

The condition for enterprises of the aluminum industry is the continuity of the technological process -- from primary aluminum to finished rolled stock. With this process, it is not necessary to cast ingots after melting aluminum in electrolyzers and then heat them up again before rolling.

The technology developed in the USSR involved the primary aluminum flowing through magnetic pipelines from the electrolyzer directly to the casting-rolling mill. A continuous casting begins to form in the mill which immediately, without intermediate heating, gets into the rolls of the continuous rolling mill. As a result, not only does labor productivity increase considerably and initial costs decrease, but electrical power is also saved (about 500 kw-hours) due to the elimination of heating the metal before rolling, as well as the loss of about 0.5% of the metal in burning.

The VNIImetmash developed jointly with two other collectives two types of machines for the continuous technology. The first of them -- machines to manufacture conductors, are called casting-rolling mills. They are used at six aluminum plants. They roll over 80% of all aluminum conductors in the country. The second type -- machines to manufacture strip up to 1600 mm wide and 6 to 8 mm thick, are called continuous casting mills that are in operation at three plants.

This efficient technology made it necessary for engineers and economists to use a new means to solve the problem of locating plants to reprocess primary aluminum into rolled stock. They must be included in enterprises which manufacture primary aluminum or located alongside them. In both cases, liquid aluminum is sent over magnetic pipelines from the electrolyzers to the casting-rolling mills without any power or fuel loss for heating the aluminum.

Closer to the Consumer and More Single-Type Machines

Criteria of solutions can also be found in locating machine building enterprises. First, they must be determined by the requirements for all types of products made by the machine building sectors. Here, it is necessary to take into consideration two basic economic factors.

The first is that machines near regions where they are used havecertain advantages since transportation costs are lower and more favorable conditions are created for machine adjustment service, their repairs and obtaining spare parts. The manufacturer has more possibilities for detailed study of his equipment in the process of operation in order to perfect the machines to improve their operating characteristics. Thus, the closeness of the machine manufacturing plant to its place of operation is a very essential indicator in the determination of the optimal location of the machine building enterprise.

The second factor that often has an opposite effect is the concentration level of single-type products. It is generally known that the higher it is, the greater the productivity of labor. In the given case, the use of high productivity automatic machine systems that consist of lines with total elimination of manual labor, as well as plants that approximate automatic enterprises, are more economically justified.

The more specialized these lines are, the simpler and more productive they are. As a result, initial unit costs are reduced. Therefore, machine building economics demands concentrated production of high volumes of single-type products on automatic machine systems.

At the same time, it should be remembered that such concentration should not change to a giant mania. Let us assume that if production of bicycles (of the widely used type) were concentrated at one plant in the country,it undoubtedly would need less labor as compared to existing ones. The operating bicycle plants in the country are basically mechanized and automated. Therefore, it is doubtful that a reduction in the labor on the manufacture of bicycles by further concentration would justify the additional costs of transporting them to consumers.

Here, it is necessary to take into account the factor that a huge economic effect is achieved when the manufacture of one or another product using manual labor is replaced by an automated machine system, if manual labor is thereby almost completely eliminated, cannot have the same effect that was obtained earlier when manual labor was replaced by machine labor even if the productivity of the lines was increased. The conclusion follows from here that machine building enterprises must be placed closer to machine users with simultaneous concentration of the production of a single-type machine building product to the optimal volumes of its output, that justify the use of automatic machines.

In other words, if a region is able to utilize a part of the machine building output of some single-type, which an enterprise plans to manufacture in the optimal volume, then the problem of location is solved uniquely in favor of the region. However, in case the demand for the product is insignificant as compared to the optimal productivity of the enterprise, it becomes more advantageous economically to organise the production of this product in the region where the demand is greatest. That part of the products which the enterprise can manufacture above the demand in that region, must be used by other regions.

It is also advantageous to locate production facilities to manufacture group A products within one or several adjacent regions. Thus, different climatic and economic conditions, for example, of Central Asian republics, northern regions and Siberia, necessitate the use of different machines, including those not needed by

other regions of the country. The production of cotton harvesting combines is entirely substantiated in Tashkent, i.e., at the cotton harvesting center. In the very near future, the creation of specialized enterprises will be required whose application will be primarily efficient in the Kazakh , Turkmen and Uzbek republics. Such machine building products include water distillers, solar energy generators, solar heaters, solar air conditioners etc.

Machines for cutting down trees and processing timbers will be used mainly in Siberia. Various specialized machines, not needed in other regions, will find wide application in permafrost regions. For example, model ETs-208D excavators are designed to dig trenches in permafrost ground when laying pipe. In the production of such machines of regional application, it is advisable to be close to places where they are used. In such cases, the following principle must be preserved: only one enterprise for each type of machines to satisfy the need for them in several regions.

Labor Productivity at Enterprises From the Standpoint of Principles of Their Location

Machine building enterprises that manufacture finished products that are of a complementing nature (about which we shall speak below) consist of three classes. The first class manufactures products individually and in small series. In view of the comparatively small quantity of simultaneously produced similar machines, the use of automatic systems here is limited. Enterprises of this class may have various productivities depending upon the size of the products.

Experimental machine building plants may belong to the first class. But, most important, in this class there are enterprises that manufacture special design machines, for example, metallurgical, power, mining, shipbuilding and other types of heavy machine building. They service the industry of the whole country. To raise the quality of such machines and labor productivity by increasing the series production nature of the manufactured products, these enterprises must be specialized as much as possible. To assign them to some region would be unjustified since the products of enterprises of this class are used in the most varied regions of the country.

The location of such enterprises gravitates toward the central region and those other regions where the necessary labor resources are available. An example of the successful location of this class of enterprise is the solution adopted in the First Five-Year Plan period on building two plants -- the Ural'skiy Heavy Machine Building Plant and the Novo-Kramatorskiy Machine Building Plant imeni V. I. Lenin. Their proximity to metallurgical industry centers played a huge positive hole in the development of metallurgical machine building, as well as in ferrous metallurgy. The planned construction in the current Five-Year Plan period of a plant in Krasnoyarsk to build powerful excavators for strip mining is fully justified. Krasnoyarsk located near useful mineral deposits in Siberia, as compared to other industrial regions, is the most advantageous place from economic and engineering position to build this enterprise. Several regions in Siberia have rich deposits of coal, ore and other minerals which can be strip mined. There is a great need for excavators with bucket volumes of up to 40 cubic meters and this will increase in the future as these areas are being assimilated.

Enterprises of the second class are characterized by the use of automated machine systems due to the centralization of production of single-type products, and to satisfy the demand of the whole country for these products. They manufacture many means of production, transport and communications. It is most expedient that they organize their production at specialized enterprises using automated flow-line machine systems. These are leading enterprises of the entire country for each type of manufactured machines, for example, KamAZ [Kamskiy Motor Vehicle Plant], VAZ [Volzhskiy Motor Vehicle Plant], Chelyabinskiy Tractor Plant, Moscow "Krasnyy Proletariy" Plant etc. Their output is used almost all over the country; therefore, the dominant factor in the locations of such production facilities is in the interest of the entire country and not only of individual regions.

One viewpoint is that machines of the considered class use a great deal of metal and, therefore, must be closer to metallurgical enterprises. One can hardly agree with that because the initial metal used is basically various types of rolled stock, manufactured at various ferrous metallurgy enterprises in the Urals, Ukraine and Siberia.

Thus, the main criteria for locating enterprises of the indicated class are proximity to the geographic center of machine consumption to reduce transportation costs and the availability of labor resources of which there will always be more where the climate is better.

Enterprises of the third class differ from the previous ones by manufacturing products more widely used, and using automatic machine systems, eliminating almost fully manual labor in all production sections. They manufacture mainly the group B of machine building output and partly the output of group A: devices and machines for medicine, televisions, telephone apparatus, radio receivers, tape recorders, passenger motor vehicles, refrigerators, washing machines, various tools, products primarily for personal use etc.

To satisfy the great demand for the indicated products, it is insufficient to have only one automatic line for each type, and some lines are required in many regions.

This type of measures make it possible to change over from dispersing semihandicraft manufacturing of single-type products among a large number of enterprises to modern technology with high productivity of labor.

Location of Enterprises Producing Complementing Machine Building Products

Different criteria must be used in locating such enterprises. Consumers of their output are of two types: first -- the basic machine supplier, i.e., the customer of complementing products and the second -- the customer who operates the machines. The manufacturer must discriminate objectively in consumer demands of the quality of his products. On the one hand, they must meet the demands of the machine as a whole and, on the other, it is important that from the operating standpoint, it does not become a sore spot.

Enterprises that manufacture complementing products are of three types.

1. Enterprises called upon to provide complementing products for a certain type of machines. For example, a plant for manufacturing the ZIL truck created several auxiliary narrow-specialized enterprises in regions where there is not such a lack of labor as in Moscow. This measure, without a doubt, is very effective. It makes possible, first, an increase in the productivity of the basic plant in Moscow for the same labor resources, and therefore, improves its economic structure; secondly, utilizes fully labor resources in small cities and settlements, especially in the winter when these resources are not being used by farms.

On the basis of the above-stated, the conclusion can be drawn that locating enterprises that manufacture large quantities of single-type machines or devices, must take into account the creation of their branches located, if possible, in regions not too far from the headquarters of the enterprise where there are labor resources or large possibilities for creating them.

2. Enterprises that provide large complementing parts for machines. Many machines, primarily for transportation, after they are fully assembled, become large and less convenient to transport. This applies especially to buses, trolley buses, combines, etc. Therefore, it is advisable to build specialized enterprises where there is a considerable demand for them for the assembly of these machines and the manufacture of their large components.

3. Enterprises for producing complementing products for general machine building use. Standardization does not reach its basic goal if it is limited by manufacturing many parts and units for the same purpose at various sectors of the machine building industry. At the same time, it is also necessary to organize their mass production. These products include fastenings, metal-cutting tools, reducers, rocker bearings, hydraulic apparatus, pumps, electrical motors, brakes, various electrical apparatus for controlling and automating machines etc. A huge economic effect may be obtained if these products are manufactured at specialized enterprises using automated high productivity machine systems.

The placement of such types of enterprises gravitates toward regions where large machine building plants are located which are users of the given products. Therefore, they must be placed on the principle of the greatest concentration of production of the same product at one enterprise. The highest efficiency and the smallest initial costs are achieved under such conditions. For example, in the bearing industry, complete specialization is implemented for each bearing independently of the place of its use. The manufacture of hydraulic apparatus, however, must be organized by almost every machine building industry. The result of this is low labor productivity and high unit capital investments.

Location of Enterprises Which Manufacture Intermediate Products for Machine Building

Ferrous metal is the basic initial material in most machine building sectors which consume over half the volume of ferrous metal. Its cost can be reduced considerably by reducing technological waste and raising the quality of the products. The centralized manufacture of intermediate products for machine building -- castings, forgings, and new efficienct types of rolled stock -- is the most efficient direction in reducing metal consumption and labor.

The basic item of the intermediate product cost is the cost of metal. Therefore, it is most profitable to locate such enterprises near a metallurgical plant or within it, as well as near plants that use those intermediate products.

Examples of such successful locations of plants for machine building intermediate products are the recently built wheel rolling mill at the Nizhnedneprovsk Pipe Rolling Plant imeni K. Libknekht and the mill for rolling shafts at the Dneprovskiy Metallurgical Plant imeni F. E. Dzerzhinskiy. A considerably part of the output of all those mills is sent to relatively nearby car-building plants -- in Dneprodzerzhinsk, Kremenchug and other regions of the UkSSR. The site, however, of the second mill for rolling RR wheels (Vyksa) was selected less successfully. It should have been closer to the large plant that manufactures eight-axle cars being built in Abakan using, in this case, steel from the Kuznetskiy or West-Siberian metallurgical plants.

Enterprises that manufacture intermediate products for machine building frequently waste fuel inefficiently on heating metal. This is done in manufacturing castings, as well as forgings, rolled intermediate products of the wheel and axle types, etc. In the first case, heat losses are produced in cooling and casting cast iron ingots and after they are cast. When the ingots are received at the machine building plants they must be heated again when melting cast iron and steel. In the second case, a similar situation arises, but with respect to the steel forgings.

Such losses may be eliminated if the manufacture of intermediate products is combined technologically with the production of ferrous metals. In manufacturing castings the problem may be solved successfully if, in casting shops, instead of ingots, liquid cast iron is supplied to the shop directly from the blast furnaces.

Long experience with the operation of 150-ton cast iron mixer type carriers to transport cast iron from the Kuznetskiy Metallurgical Plant to the conversion shop of the West-Siberian Plant over the MPS [Ministry of RRs] RR tracks (a distance of about 35 km) attests to the possibility of transporting liquid cast iron over long distances. Cast iron carriers of smaller load-carrying capacities may also be built depending upon the amount of cast iron required for the casting shops of the machine building plant. In receiving molten cast iron it would not be necessary to use power or fuel to melt the metal, only for its heating with simultaneous refining and alloying. Therefore, it is expedient to locate production facilities for ferrous metal castings within the metallurgical enterprise or near it, providing for the possibility of transporting liquid cast iron.

In manufacturing rolled steel intermediate products, there are two versions of obtaining initial ingots -- casting them in molds and continuous casting. The latter has many advantages as compared to casting in molds. It is especially advantageous if done on horizontal machines by the method developed by the VNIImetmash.

Ingots of any cross section including round and multisided may be cast, then cut with a shock action saw into intermediate products of the required lengths and sent directly to thermostatically controlled furnaces for equalizing the temperature. Thus, special heating of the ingots is eliminated before the following processing in a press or on a rolling mill.

The technological joining of machine building intermediate products with ferrous metallurgy on the basis of continuous technology -- from liquid metal at the stage of its reception to the final part -- is an efficient way to reduce the consumption of fuel-power resources. For its realization, it is expedient to locate enterpises for producing machine building intermediate products in regions where machine building is developed. In this case, the technological wastes originating at machine building enterprises may serve in the same region as initial products for steel production while the technology by the method of the liquid metal-finished part to obtain intermediate products would be entirely feasible for the machine building enterprises of this region. Then locating production facilities for machine building intermediate products in a complex with furnaces for melting scrap in the region where scrap is formed may be acknowledged as the most optimal. Its efficiency would be still higher, if processes of rolling and part rolling mills, developed by the VNIImetmash are used in manufacturing many intermediate products.

The above analysis of factors affecting the optimal location of machine building enterprises permits making the following conclusions.

The economics of the machine building enterprise require the greatest possible concentration of enterprises which manufacture single-type or identical products. The combination of this principle as an efficient direction for the automation of production with the interests of the region, or several adjacent regions -- is the main condition for the successful location of enterprises.

The greatest possible proximity of the production facilities of products of machine building to the point where they are used is good practice not so much from the reduction of transportation costs as from raising the efficiency of producing the parts. The proximity of the machine manufacturer to his consumer simplifies the organization between them of an adaptive system that affects the increase in the quality of the machine in the process of its manufacture and operation.

Machine building enterprises of general union purposes, as large series production as well as individual production, gravitate toward the central regions of the country where natural conditions facilitate the growth of labor resources.

The organization of production facilities to complement products at independent enterprises or branches and their locations in regions where labor resources are more plentiful, is one direction for raising the profitability of machine building.

A large economic effect may be obtained when the organization of production of intermediate products using a large amount of metal for machine building is done in technological association with metallurgical production facilities. This effect may be especially considerable when the association occurs on the basis of creating a single process -- from liquid metal, at the stage of its production to the finished product.

2291
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INTRABRANCH REDISTRIBUTION OF FINANCIAL RESOURCES DISCUSSED

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[Article by T.V. Selezneva, senior scientific research fellow, Scientific Research Finance Institute (NIFI), candidate of economic sciences, and V.A. Romanenkova, senior economist, NIFI: "Intrabranch Redistribution of Financial Resources"]

[Text] Conversion of industrial branches to the autonomous accounting methods of operation and standardized distribution of profit is accompanied by an increase in the proportion of their own resources to the total volume of their assets and an expansion of the scope of intrabranch redistribution. Economists evaluate the increased volume of redistributed resources differently, as there is no single opinion as to the correctness of redistribution processes within a branch. Some negate their efficacy as ways to create financial resources, while others hold the opposing viewpoint and include redistribution processes in the sphere of autonomous accounting relationships.

Redistribution relationships within the branch (sub-branch) are dictated by the necessity for centralization of monetary assets at the disposal of the management agency for financing of general branch (general association) programs, funding of work to develop science and technology and for the operational shifting of resources during plan realization. Another reason for intra-organizational redistribution of resources is that the requirements of enterprises and associations for funds do not always coincide with their own sources both in terms of volume and time. As a result, shortages or surpluses of funds result. Through the system of intra-organizational redistribution, these deviations are diminished.

The experience of ministries converted to the autonomous accounting methods of operation demonstrates that the redistribution processes are not being developed everywhere with like intensity. The volume of intra-organizational redistribution generally speaking, is increasing sharply in those branches which have converted to full self-support through financial resources and have totally relinquished budgetary allocations. If in the Ministry of Instrument Making, Automation Equipment, and Control Systems (Minpribor) intrabranch redistributed resources increased by almost a factor of 10, no substantive changes occurred in their volume within the Minstry of Heavy Machinery Manufacture (Mintyazmash) and the Ministry of Power Machine Building (Minenergomash). This is tied to the fact that in the above named ministries, budgetary financing remains one of the sources of creating financial resources.

The scale of development in the redistribution of resource processes in those branches can be judged according to the following data. In Mintyazmash by plan for 1981, 3.2% of profits was redistributed among VPO (at the ministry level), by which 4.2% of plan expenditures was financed. At the level of individual VPO, from 1 to 11.2% of profits was redistributed. In the Minenergomash by plan for 1981, profit derived from enterprises as redistribution (after deducting for financing) constituted 5.7% of balance profit, or 8.4% of profit remaining at the disposition of the branch. Redistributed profit covers 6.7% of plan expenditures.

Intrabranch redistribution of current assets has considerable significance for individual enterprises. Through these, 38% of the growth in the standard for current assets was covered for the 1981 plan at the Belgorod Power Machine Building Plant.

The portion of amortization for remodeling redistributed at the branch level (among the VPO) in Mintyazmash according to the plan for 1979 was 5.1%, and for 1981 was 0.6% of the total of amortization allowances for capital investments. In Minenergomash for the period 1979-1980, up to 2% of additional amortization for capital investments was redistributed. On greater scales than remodeling or renovation allowances, amortization allowances for major overhaul are redistributed. The ministries are vested with the right to establish a reserve of amortization allowances for major overhaul up to 15% of the total of these allowances. A portion of this reserve is allocated for disposition by the VPO.

Financial resources within the branch (sub-branch) are redistributed via a system of centralized assets and reserves or by direct withdrawal of assets from certain enterprises (associations) in favor of others (the so-called "non-asset" redistribution). Centralized assets and reserves of ministries and industrial associations are created, as a rule, by enterprises and production associations making up the production-management complex. A source for creating certain assets and reserves for the VPO are the assets of capital and reserves transferred to the VPO by the ministry.

Consequently, the centralized assets themselves and the reserves of economic maneuvering are the result of development of redistribution relationships at the level of ministries and industrial associations. Through the redistribution of profit, amortization allowances, and other sources, a unified fund for the development of science and technology (EFRNT) is established, as are a financial assistance reserve, a reserve of amortization allowances for major overhaul and the like. Having the centralized assets and reserves, the management element has the capability to operationally influence the subordinate enterprises and organizations and to create normal conditions for their operations.

A substantial portion of profits and current assets is redistributed by bypassing assets and reserves, i.e., as direct withdrawals from certain VPO and enterprises and the financing of others. The ratio of asset and non-asset redistribution of resources within the branch and sub-branch can be judged to a degree by the portion of profit directed to the EFRNT and to ministry reserves (for economic incentive funds, financial assistance funds), and by the profit withdrawn as redistribution from the VPO and enterprises.

Computations indicate that in Mintyazmash (according to the plan for 1981), 8.2% of profit was distributed via centralized assets and reserves, and 3.2% directly among the VPO. In Minenergomash, profit redistributed via assets and reserves comprised 10.3% of the balance profit for the branch, and non-asset redistribution constituted 5.7%.

The development of autonomous accounting financing of plan expenditures and the expansion of the sphere of standard-share distribution of profit substantially strengthens the role of internal branch resources in the reproduction process. However, this does not mean that the development of every branch will be totally dependent upon its capabilities. A shortage of its own financial resources when necessary can be covered through employment of credit and budgetary allocations. An optimum combination of these methods to create financial resources (with allowance for the advantages of each) must promote the effective use of assets and consolidation of autonomous accounting relationships within the production-management complex.

The budget method provides for accumulation and direction of monetary assets to the most important sectors of the national economy, and provision of timely and complete financing of branch plan expenditures. However, withdrawal of profit from enterprises and the allocation of budget assets for the replenishment of the standard of individual organizational working or current assets, capital investments, and other items reduces their interest in the results of the management operation. Shortcomings of this method also include the fact that the budget allocations unused in the current year are closed out. As a result, the enterprises attempt to expend those assets prior to the end of the year, with no consideration given the economic efficacy of the expenditures.

Differing from budget allocations, bank credit as a method of creating financial assets satisfies to a great extent those requirements for the consolidation of autonomous accounting and increases the responsibility of the branch for final results in operations. The employment of credit expands the capabilities of the branch for financing expenditures associated with effecting capital investments and improvements in production. In addition, the principles of credit (return and outlay) constitute a powerful and important stimulus for improving production efficiency and in guaranteeing profitability.

Nevertheless, in actuality, redistribution processes precede the attraction into branch circulation of credit system assets. Such an active position on the part of the ministries regarding redistribution processes cannot be considered without basis. It must be considered that for enterprises and associations those assets obtained from superior organizations are attracted (external) sources of resource formulation. For ministries, the resources of the VPO and for the latter, resources of subordinate production associations and enterprises constitute their internal resources, inasmuch as the topic is the unified production-management complex (the branch as a whole or the sub-branch). Therefore, obviously it is illogical to enlist credit when intra-organizational resources are available--even more so because of the interest assessed for the use of loans.

If one evaluates the effectiveness of redistribution processes for assets of individual economic elements or links in the branch from the standpoint of the

autonomous accounting organization, certain deficiencies of the intrabranch redistribution of financial resources must be noted. They are manifested primarily in that assets obtained by enterprises (associations) through redistribution not subject to repayment in effect do not differ from budget allocations, which engenders dependent attitudes. Moreover, a lack of interest on the part of the enterprises in the timely transfer of redistributed assets does not always ensure their regular availability to those who require them. From those standpoints, the advantages of credit are obvious.

However, considering the objective conditionality of intra-organizational redistribution of resources both at present and for the future, it is imperative to not generally curtail the redistribution processes, but to develop them on economically efficient scales. In this respect, the point of discussion must be on the limitation of non-plan intrabranch redistribution of financial resources.

Negative aspects of redistribution processes include specifically that in those branches converted to the standardized method of profit distribution, "the interbranch redistribution of volumes and sources for the financing of capital investment is...a permanent reason for the adjustment of quarterly and annual plans"[1]. In Minpribor, for example, assets designated for the acquisition of equipment are re-distributed among the associations practically on a quarterly basis. The reason for this lies basically in the tardy delivery of equipment, lack of project readiness at those sites which were to install the equipment, and violation of plan deadlines by the construction organizations for the completion of construction-installation operations, which results in individual associations and enterprises having unused assets. The ministry, striving to rationally and more fully utilize these assets, annually during the IV quarter redistributes them among the VPO and the enterprises, which leads to changes of financial plans and standardized allowances of profit.

The unfounded non-plan redistribution of financial resources can be a consequence of the violation of financial discipline by an upper eschelon organization. There are instances when the superior element, utilizing the right to redistribute the profits of subordinate organizations, withdraws assets with no allowance for the fulfillment of the profit plan by enterprises. There is also the practice of withdrawal and redistribution of a portion of the assets in the amortization fund for major overhaul which are not subject to repayment. Increasing the responsibility of superior organizations for prohibition of non-plan redistribution of financial resources is an important reserve in reducing the volume of redistributed resources and of negative consequences associated with that volume.

Redistribution processes must be developed in economically justified forms and require appropriate organization and the establishment of limits within which those processes will not conflict with goals for consolidating autonomous accounting relationships within the branch (sub-branch). This assumes the improvement of the existing practice for redistribution of financial resources.

Intrabranch redistribution of those resources must be effected on a normative or standardized basis, primarily through a centralized system of assets and reserves which is, in our view, its most advanced form. With correct organization, such a procedure ensures a plan-conforming centralization of resources at the branch

(sub-branch), improves control over formulation and movement of monetary assets and expands the opportunities for their efficient use. Standardization documents define allowable (limiting) norms of allowances for centralized assets and reserves.

Conversely, the non-asset redistribution process is characterized by a high degree of uncertainty as to its volumes, is subject to frequent changes and corrections, and is frequently effected in a non-plan manner, which is contrary to the goals of consolidating autonomous accounting. Therefore, a reduction in the volume of non-asset redistribution of financial resources is an important direction for improving the practice of intrabranch redistribution. This problem apparently will be resolved in part through the establishment of standards for individual organizational working assets and coordinating them in accordance with existing requirements of branches, VPO, and individual enterprises for working assets.

A reduction in the non-asset redistribution of financial resources would be facilitated by increasing the size of various centralized assets and reserves and also improving the practices of formulating and using those assets. The volume of centralized assets and reserves must determine the extent (limits) of intrabranch redistribution of resources. Practice indicates that not all branches possess equal capabilities in the formation of these assets and reserves, which their sizes bear witness to. If in Minpribor during 1980, the reserve for financial assistance in percent of the standard for individual organizational working assets was 3.3, in Mintyazmash it was 0.9, and 0.6 in Minenergomash. The shortfall in individual working assets the same year exceeded the volume of this reserve in Mintyazmash by almost a factor of 10, and in Minenergomash by 14.5. Below the established limit standards also were reserves in the plan formulated by the establishment for enterprises of elevated (more intensive) plan goals for individual indicators or the non-distribution of portions of resources allocated for their disposition.

We have already proposed, in establishing the size of the financial assistance reserve, using not profit as the basis (growth in profit), but the standard for individual working assets to establish the size of the financial assistance reserve at a level of 5% of the individual working asset standard and to establish it not through reduction of the standard (as was done prior to 1967), but by profit2. It would be necessary then to also expand the target-directed purpose of this reserve. Under conditions of converting the branch to autonomous accounting methods of operation, the financial assistance reserve may be assigned another function--that of insuring guaranteed payments to the budget (regulating of interrelationships with the budget) in the instance of nonfulfillment of the plan for profit by individual sub-branches or the branch overall. In order to guarantee creation within established sizes of reserves for profit, sales volume, wage fund, etc., and in this to avoid infringing upon or detriment to the interests of the enterprises and associations, such reserves must be provided for at the plan compilation stage with allowances made for additional requirements for assets to create those reserves.

Certain changes should be introduced in the practice of formulating the reserve for amortization allowances for major overhaul. With the existing procedure for use of this reserve created in Mintyazmash, it is, in essence, a centralized fund for major overhaul. Actually, the reserve is only a part, remaining for unforeseen cases to finance operations not envisaged in the plan. Inasmuch as

its size is insignificant, non-plan operations for major overhaul, the cause of which might be breakdown, natural calamities, etc., frequently are financed by withdrawing (immobilization) enterprise working assets for this purpose. Therefore, the ministry and VPO must be provided for in the case of unforeseen expenditures, with a larger portion than currently is the case of reserve assets and such expenditures compensated by the non-distributed reserve. This is particularly important, because the plan volume for major overhaul the next year is reduced by the amount of immobilization.

In our opinion, the volume of major overhaul in the enterprises would be more correctly planned not as the remaining total of amortization allowances for these purposes (less allowances to the reserve of the ministry and the VPO), but with consideration of actual requirements for overhaul, based upon the condition of fixed assets. Possibly, it would be in the interest of efficiency to disseminate to other branches the know-how of Minenergomash in formulating the reserve of amortization allowances for major overhaul, differentiating the amount of withdrawal of assets dependent upon the growth composition of fixed assets and the planned volume of major overhaul for individual enterprises. Moreover, the ministries must more widely utilize the right of differentiating amortization allowances to the reserve for major overhaul and to establish a higher norm or standard for allowances for new enterprises and those having a significant proportion of high-cost equipment not requiring major overhaul in the first years.

The development and consolidation of intrabranch autonomous accounting assumes a strengthening of the principles of equivalency and repayment in relationships among the production elements. These principles should be the foundation of redistribution relationships within the branch. In our view, all enterprises, with the exception of planning-unprofitable and low-profit potential, should participate in the formation of centralized assets and reserves. Assets from this capital and reserves would efficiently be allocated primarily on the conditions of return and possibly, outlay. In our opinion, it makes sense to introduce payment for the use of a repayable loan issued from the financial aid reserve on a scale not lower than the bank interest (with payment of it through profit remaining at the enterprise's disposal). This does not exclude, however, non-compensatable rendering of assistance to enterprises (with allowance for the reasons underlying the organization's specific financial difficulties).

In conditions of developing redistribution processes within the branch (sub-branch), resources and capabilities for financing of plan expenditures are greatly dependent upon the timeliness and completeness of asset contributions coming into the enterprise or association in the form of redistribution. Violations in the transfer of assets to centralized funds and reserves create specific financial difficulties for individual enterprises and associations, and for the branch overall. A study of the experience of Mintyazmash and Minenergomash indicates that not always are the deadlines observed.

For timely provision to the enterprises of financial resources, it is necessary to oblige the Gosbank to issue credit to the enterprises upon the orders of the ministries and the VPO for withdrawal of amortization, as is accepted in the redistribution of working assets and profit. It is also expedient to extend the current 20-day period for granting credit for such purposes. To insure complete

payment and to increase the responsibility of the enterprises for timely contribution of assets to the financial assistance reserve it would be indicated that enterprises be granted deferments in the payment of significant repayable loans issued from the reserve, and in remaining cases to impose sanctions in the form of a levied increased interest rate in the violation of deadlines for the plan deductions to the reserve and for debt liquidation. To a certain degree, this is also applicable for other centralized assets and reserves. According to the experience of the Czechoslovak Socialist Republic, fines imposed by higher eschelon organizations upon subordinate associations and enterprises for late contributions to centralized funds and reserves could be incorporated in those funds together with other sources for creating such funds.

In conjunction with improving the organizational structure of management for the national economy, the problem of the level of redistribution of branch financial resources assumes great significance, which, in essence, is the redistribution of centralized funds and reserves among VPO and the ministry. Practice indicates that the capabilities of the associations to operationally shift financial resources are still limited.

An increase in accordance with the decree of the CPSU Central Committee and USSR Council of Ministers number 695 in the standard for deductions to the amortization reserve for major overhaul (from 10 to 15%) did not affect Mintyazmash VPO. They retained, as previously, 5% of amortization deductions for major overhaul at their disposal, when at the same time not 5, but 10% of such deductions went to a similar reserve of the ministry. The requirement for assets for effecting major overhaul within the VPO somewhat increase the size of the association reserve for these purposes. At the same time, at the ministerial level, unexpended assets (carry over remainders) of this reserve remain.

Centralized assets and reserves of the branch should be distributed among the ministry and the VPO in such a way that the greater portion remains at the disposition of industrial associations. Here, consideration must be afforded branch capabilities and the requirements of each VPO for assets. Ministerial centralized resources might augment the system of assets and reserves of the VPO and utilized to replenish (in case of necessity) and for general branch needs. It would be efficacious to provide all industrial enterprises the right to have a reserve of financial assistance (currently this question is resolved at the discretion of the ministry), and possibly, under the aforementioned decree, a reserve for capital investments, construction-installation, and contract work.

FOOTNOTES

1. G.S. Mergelov, "Khozraschet v Sisteme Upravleniya Otraslyu" [Autonomous Accounting in the Branch Management System], Moscow, Ekonomika, 1980, p 170.

2. "Finansy SSSR" [USSR Finances], No 4, 1981, p 19.

8851
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BRIEFS

HEAVY MACHINE BUILDING DEPUTY MINISTER'S DEATH--[Obituary of A.G. Eysmont] Andrey Grigoryevich Eysmont, member of the CPSU and deputy minister of heavy and transport maching building, died suddenly on 11 December 1982. A.G. Eysmont was born 16 August 1910 in a peasant family in the village of Bovkun in Tarashchanskiy Rayon, Kiev Oblast. [Signed] A group of comrades [Excerpts] [PM051131 Moscow SOTSIALISTICHESKAYA INDUSTRIYA in Russian 15 Dec 82 p 5]

CSO: 1823/24

UDC 658.516:658.512.624

USES OF NC MACHINES DISCUSSED

Moscow MASHINOSTROITEL' in Russian No 9, Sep 82 pp 38-39

[Article by engineers G. I. Bliznyukov and B. I. Tsukrov: "The Peculiarities of the Development of Finished-Product Works"]

[Text] The specialization of production subdivisions is in many ways promoting the efficient use of NC machines. The development of such works requires a new approach to the solution of a number of questions of technological designing. Thus, when organizing sections of the finished-product manufacturing of parts on NC machines it is necessary to develop standard technological processes of the complete machining of the parts and grouped operations which ensure the optimum loading of the machine tools.

The finished-product manufacturing of parts on NC machines at the Gryazi Plant of Hydraulic Equipment is based precisely on the combination of the methods of the standardization of technological processes and the principles of grouped technology.

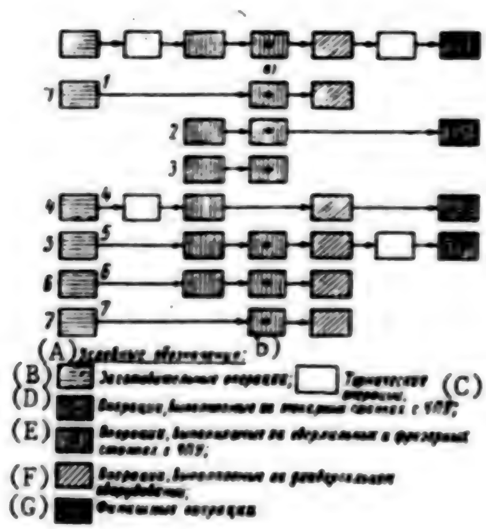
The parts planned for machining on NC machines have been reduced at this plant to the minimum number of types. Parts, which are similar in design features and can be machined in accordance with a common technological process, have been included in each type. Such requirements as the maximum transfer of the labor intensiveness of the machining of parts to NC machines and the continuity of the performance of operations on equipment of the same type, which ensures the greatest efficiency of the operation of NC machines, were taken into account when developing the standard flow route processes.

The main feature of the integrated flow route of machining on NC machines for the finished-product sections is the observance of the continuity of its stages. Each stage can consist of several operations. Here the labor intensiveness of the machining of the parts on NC machines amounts on the average to 80 percent to the labor intensiveness of the machining.

The diagram of the integrated flow route and examples of the organization on its basis of standard flow routes of the machining on NC machines of parts: 1--large plates; 2--flange cylinders; 3--round heads; 4--rods; 5--values, 6--half-couplings; 7--small plates, are shown in the figure respectively by a and b.

Thus, the integrated flow route consists of seven stages of the machining of the part, each of which is a complete cycle on a specific type of equipment and is

performed in a specific sequence. The standard routes consist of a different number of stages, but contain without fail the stages of machining on NC machines. For example, the flow route of the machining of parts like large plates consists of three stages: at the first is machining on semi-automatic planer-type milling machines; at the second--on NC drill presses; the finishing of complicated intersections of holes and the cutting of special threads--on general-purpose equipment. Parts like round heads are produced entirely on NC machines, while parts like flange cylinders also undergo finishing treatment (the honing of the central hole). The routes of the machining of parts like rods and valves, which, in addition to basic machining on NC machines, include heat treatment, the machining of additional surfaces on specialized machine tools and the polishing of the working surfaces at the stage of finishing treatment, contain the majority of the stages. Three stages of the integrated route: the machining of the parts on lathes, drill presses and milling machines with numerical control and their finishing on general-purpose and specialized equipment, are performed at the finished-products works.



Key:

A. Key
B. Blank-preparing operations
C. Thermal operations
D. Operations performed on NC lathes
E. Operations performed on NC drill presses and milling machines
F. Operations performed on general-purpose equipment
G. Finishing operations

The range of NC machines, the diagrams of the location of the parts during machining and the machine tool intensiveness of the operations are determined on the basis of the standard flow route processes. All the types of parts are broken down into classes, subclasses and groups. The type of NC equipment, on which their basic machining is carried out, is taken as the criterion for uniting the parts into classes. When breaking the classes of parts down into subclasses the profitable loading (not less than 85 percent) of NC machines, which are similar in models, with parts of technologically similar types serves as the criterion. When

creating a group the possibility of organizing for the parts included in it a grouped operation which is characterized by the common nature of the equipment, the equipment accessories, the adjustment and the manufacturing steps, is provided for. If the parts of a single subclass also have the attributes of a group, they are not subject to further grouping.

Thus, all the types of parts, which are machined on NC machines, form: the class of flat parts which are machined mainly on machine tools like drill presses and milling machines, in which the rotation of the tool is the main movement, and the class of parts like bodies of revolution, which are machined mainly on machine tools like lathes, of which the rotation of the part is the main movement. The parts of the first class are broken down into five subclasses (for example, large plates, small plates, sheets and others). Seven subclasses are formed in the second class (for example, large flanges, half-couplings, round heads, valves and others). The subclasses, which also have attributes of groups, do not undergo further division. The remaining subclasses are broken down into groups. Thus, the subclass of round heads contains the following groups: round heads, cylinders, small flanges, valves, sleeves, medium-sized flanges, rods.

The organization of a shop of the finished-product manufacturing of parts on NC machines with two production sections: the machining of flat parts and the machining of parts like bodies of revolution, is advisable on the basis of such a classification. The arrangement of the equipment with allowance made for the formed subclasses and groups of parts ensures its optimum loading and makes it possible with the minimum number of readjustments and transportation operations to perform the entire cycle of the machining of the parts.

The implementation of the grouped method of machining parts makes it possible to fit NC machines with quickly readjustable accessories with general-purpose pneumatic drives of the rapid securing of the parts and with elements of a group orientation with reference to the system of coordinates of the machine tool, as well as with devices for the mechanized and automated loading of the machine tools.

For example, an accessory with interchangeable and controllable elements, which ensure the securing of all the parts of the group, the positioning and removal of the parts by means of a manipulator with manual control, has been designed for the machining of parts like large plates. A grouped multiposition accessory with common mechanized drive is envisaged for the machining of small plates, while a readjustable hydropneumatic table with power units, which are located around the periphery, is envisaged for the machining of parts like sheets. The machine tools, on which the group of parts like valves is machined, are fitted with automatic manipulators for their positioning and removal.

The development of the finished-product manufacturing of parts on NC machines with the use of the principles of the standardization of technological processes and grouped technology ensures the loading of such machines at the level of not less than 85 percent. The use on them of mechanized grouped quickly readjustable accessories and tool adjustments decreases to one-third to one-half the time of readjustment of the machine tools. The efficient use for the loading and unloading of the machine tools of automatic manipulators increases the coefficient of multiple-machine attendance and decreases the number of operators by approximately 1.5-fold. Moreover, the time for developing control programs is decreased by three- to fourfold.

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INSTITUTE'S INVENTORS DEMONSTRATE THEIR WORK

Moscow MASHINOSTROITEL' in Russian No 9, Sep 82 pp 41-42

[Article: "The Innovators of an Institute Exhibit Their Developments"]

[Excerpt] The inventors and rationalizers of Leningrad and the oblast are constantly exhibiting their innovations in the showrooms of the House of Scientific and Technical Propaganda. Specialists of the All-Union Planning and Technological Institute of Power Machine Building, who are showing at the exhibition their developments, which have been successfully adopted at the plants of the sector and the country, are taking an active part in this. Some of them are indicated in the article.

The semi-automatic line for the production of precision-cast parts, which has been introduced at the Turbolopatka Industrial Association, makes it possible to mechanize a number of difficult and harmful technological operations in the production of especially complicated castings of turbine blades, segments, nozzles, propellers and other items. Thus, for example, the blade of a 1.5-m propeller is cast on the line without allowance for machining. The technology of the casting is simple.

On the vibrating table of the pneumatic molding unit they place an empty casting box, pour fireclay powder into the bottom of it from a hose, place a ceramic casing on it and mold it with a supporting filler, turning on the vibrating table for 10-15 sec. The shaped casting box is delivered by conveyor (inventor's certificate 430958) to the assigned furnace groove, the furnace door automatically rises and the push rod in two working strokes feeds the casting box into the furnace. Here all the casting boxes in the furnace advance one step, while the leading one finds itself at the exit door. On a command from the main control panel the door rises, and the push rod in two working strokes moves the red hot casting box onto the casting conveyor. If necessary four casting boxes can be simultaneously fed onto the conveyor.

On the casting conveyor the ceramic casings are blown out by an injector and are filled with molten steel by means of mechanized ladle hangers. The filled casting boxes are transported by conveyor to the secondary furnace and are transferred to lateral water-cooled conveyors, which step by step transport them through the zone of air cooling to the knock-out conveyor, and then to the manipulator, which automatically stops the conveyor upon the entry of the next casting box into the hydraulic clamping device. The manipulator removes the casting box from the conveyor and rotates it 140° (here its contents are poured onto the screen of the separator),

and then returns the empty casting box to the conveyor. On its next step it is again put on the vibrating table. The productivity of the line is 1,000 tons a year.

The mechanized line is intended for the production of coils of water economizers and superheaters of steam boilers, as well as other items which have the form of planar coils with a constant distance between the centers of the radii of the bends. It includes: a machine tool (inventor's certificate 662198) for the cold mandrel-less bending of coils from a length; a cutting-off machine for the cutting of the tube with a tool head; two trimming machines, which trim the outer surface of its ends with needle cutters; two facing machines, which bore out the inside diameters of the ends of the tubes and remove the chamfered edges (for welding); a butt welder, on which the skelps of the tubes are welded into a length by contact electric welding; roller tables and racks. The tubes and lengths are transported by special mechanisms.

The bending of the elements of the coil is carried out in a continuous sequence with simultaneous sizing. The number of loops is determined by the design of the coil and in practice is not limited. The machine tool is incorporated in the mechanized line and makes it possible to carry out the subsequent automation of production.

The line has been introduced at the Tsentrkazenergoremont Production and Repair Enterprise with an economic impact of 188,700 rubles.

A machine tool (inventor's certificate 691227) for the bending of the tubular and core elements of heat exchangers, which have identical dimensions of the initial billets--a pipe or core with V-shape (a diameter of 10-20 mm)--has been introduced at the Podolsk Machine Building Plant imeni S. Ordzhonikidze. The machine tool operates in the automatic mode. Each of the branches of the billet undergoes bending through a curve with different parameters of curvature and additionally on straight sections. The bending is carried out on a cushion under the action of pressure rollers, which move along the branches of the billet from the top to the ends. By changing the forces of the action and regulating the hardness of the cushion, runs with different parameters of curvature (a radius of 200 to 2,000 mm) are obtained. The machine time of the bending is 40 sec.

The economic effectiveness from the introduction of the machine tool comes to more than 240,000 rubles.

A semi-automatic machine (inventor's certificate 393034) for the production of salt models of turbine blades and other items in water-cooled metal press molds with one vertical jointing plane has been introduced at the Turbolopatka Industrial Association. The semi-automatic machine can be used in series and large-series production, which involve the production of precision-cast items made from steel and high-temperature alloys with a weight of up to 160 kg. It ensures:

the high quality melting of the model mixture, without overheating, and the short-term holding at the melting temperature of a portion of the melt;

the pouring of the melt into the press mold using a ladle by turning the platform with the press mold and the ladle, the set time lag for the building up of the

walls of the model of a specific thickness, the pouring into the ladle of the unhardened portion of the melt for obtaining a hollow model;

the desired holding for the complete cooling of the model in the closed press mold;

the broaching of the press mold in one direction (a hydraulic broaching cylinder with guides and an arched clamp with platforms for the securing of the inserts of the press molds, which are being broached, is mounted on a rotating work support arm, which moves along the two guides);

the parting of the press mold (the parting time is shortened considerably due to the rotating work support arm);

the rotation of the mold section with the model to a position which is convenient for the operator when removing the model;

easy access to the open press model during inspection, cleaning and coating;

safe work due to interlocks (there are two control levers of the closing of the mold sections).

The semi-automatic machine has been completely converted to hydraulic operation. The control system ensures both manual and automatic control of the semi-automatic machine in the process of the assembly and disassembly of the press mold. The automatic cycle of operation includes the following operations: pouring, crystallization, turning for pouring, holding for pouring, holding for complete cooling, turning to the initial position, broaching, the parting of the press mold, turning of the mold section for discharge. One operator attends two semi-automatic machines. The annual economic impact from its introduction is 60,000 rubles.

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AUTOMATED LINES, METAL CUTTING MACHINE TOOLS

Moscow STANDARTY I KACHESTVO in Russian No 9, Sep 82 pp 11-13

[Article by V. S. Belov, general director of the "ENIMS" NPO [Scientific Production Association] and N. F. Khlebalin, manager of the ENIMS department]

[Text] Unified standardization programs that provide for the development of interrelated technical norm documents for all stages of production are an efficient means for raising the technical standard and quality of production. This, in particular, is attested to by the experience of the machine tool industry where a number of unified programs was realized in the 10th Five-Year Plan period. Developed by a specialized industrial sector organization on standardization -- Experimental Scientific Research Metal-Cutting Machine Tool Institute (ENIMS) -- and enterprises of the sector, unified programs for standardization made it possible to raise considerably the technical standard of metal-cutting and unit head machine tools for machine building*.

At present, a new unified program for standardization is being put into practice, "Automatic lines, automatic machines, semiautomatic machines, progressive metal-cutting machine tools for machine building and metal-working for 1981-1985," developed for the purpose of providing technical norms to insure the implementation of tasks to raise considerably the technical standards, competitiveness and accelerated development of the production of high-productivity and precise metal-cutting equipment, and raising by 1986, as compared to the level achieved in the 10th Five-Year Plan period, the productivity of metal-cutting machine tools by 1.5 to 1.6 times; of manufacturing precision by 1.2 to 1.3 times; and of reliability and length of service life by 1.5 to 1.5 times. The structure of this program is shown on the circuit.

In accordance with the basic programs above, 60% of the program subjects are devoted to the development of technical norm documents that regulate the requirements of the final product.

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* See: Prokopovich, A. Ye. Unified programs for standardization in the machine building industry. STANDARTY I KACHESTVO, 1982, No 3.

1. Unified standardization program
2. Final product
3. Raw and other materials
4. Complementary products
5. Technical production means
6. Metrological facilities
7. Typical technological processes and norms
8. Preparation and production organization norms
9. Operation, technical servicing and equipment repairs
10. Automatic lines, including re-adjustable ones and with ChPU [Numerical Program Control]
11. Automated sections of machine tools with ChPU computer controlled
12. Metal-cutting machine tools with ChPU
13. Metal-cutting machine tools without ChPU

The program is interrelated with the following programs:
A system of numerical program control;
Preparation of control programs for machine tools with ChPU;
Cutting and auxiliary tools for machine tools with ChPU and automatic lines;
High-productivity metal-cutting bit tool for machine tools and automatic machines;
Program for providing metrological equipment to Minstankprom [Ministry of Machine Tool and Tool Building Industry];
Specialized unified programs to raise the productivity and accuracy of metal-cutting machine tools and the reliability of metal-cutting machine tools and automatic lines;
Unified program of introduction of YeSTPP [Standard System for Technological Preparation for Production].

For the first time, the development of a number of norm documents on automatic lines for machine building is involved. The following will become objects of standardization, in particular: nomenclature of the basic indicators of the technical standard and quality of products; terms and definitions, including those for readjustable lines; satellite devices to transport intermediate products processed in the line; typical methods for selecting basic materials and calculating the productivity of automatic lines made up of aggregated machine tools; the behavior of the receiving-releasing of mass production automatic lines with respect to indicators of reliability and accuracy of machining at the manufacturing plant etc. The developed technical norm documents will facilitate the creation of high productivity and reliable automatic lines.

For the first time, the program involves the development of norm documents for a new type of equipment for machine building -- automated sections of machine tools with program control, controlled by computers. Such progressive equipment insures a fuller loading of machine tools with ChPU and a higher productivity of three to five times for multinomenclature production. In this section of the program, it is planned, for example, to develop standards for classification, terms and definitions, general technical requirements, a method for evaluating technical-economic efficiency and the determination of the area of application.

A large section of the program consists of developing norm documents for metal-cutting machine tools with ChPU, used widely in various sectors of industry. The program involves the development of standards for the preparation of control programs, and the development of input language for automatic preparation of the computer control program for additional test accuracy norms, for reliability norms, for the number of units and mechanisms etc.

It is also planned in the program to develop technical specifications for new automatic lines, computer controlled automated sections and a large number of machine tools with ChPU for the needs of the national economy.

The program involves unified standardization and a new direction of re-equipment of various sectors of the industry -- metal-cutting machine tools, equipped with industrial robots (manipulators) with program control. The program involves the development of technical specifications for a number of various types of metal-cutting machine tools with industrial robots (manipulators) and other technical norm documents.

Inasmuch as the products of the machine tool building industry affect all machine building sectors and there is the possibility of producing new products, a great amount of prior attention was devoted to questions of developing state and industrial standards in this area. Therefore, at the present time, state and industrial standards cover 97% of the product nomenclature manufactured by metal-cutting machine tools. Nevertheless, the program envisages the development of a number of standards for metal-cutting machine tools. Basically, this is equipment for laser, ultrasound, mechanical-plasma machining, which is promising for certain types of materials.

The program provides for developing a number of general norm documents for automatic machines, semiautomatic and other types of machine tools, including general technical specifications for product manufacturing, technical noise norms etc.

For the efficient utilization of materials and reduction of electric power consumption in machine tool operation, the development of an industrual sector standard is specified which regulates the order of obligatory inclusion of corresponding indicators in the technical specifications for basic types of series manufactured metal-cutting machine tools. The standard includes progress requirements for raw and other materials which must provide a higher quality and reliability of the automatic lines and of the metal-working equipment.

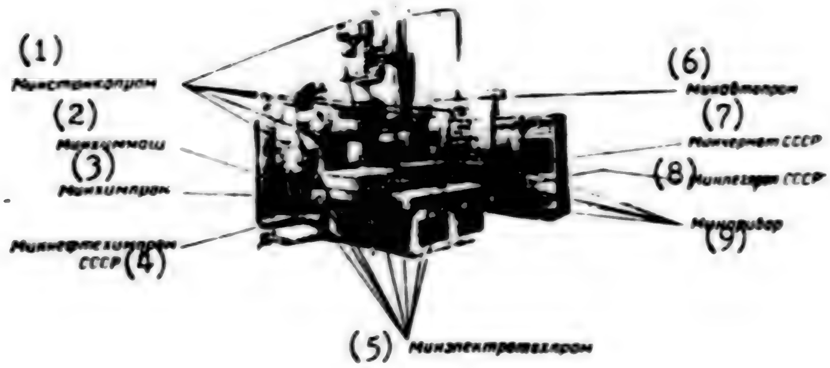
The technical standard of modern metal-cutting machine tools and automatic lines depends, to a considerable extent, on the quality of the complementary electrical equipment products and the numerical program control systems. The program envisages the development of standards on comprehensive devices for controlling the electrical drives for metal- and wood-working machine tools, unified drives with frequency-controlled synchronous motors and semiconductor power devices, drives for metal-cutting machine tools using non-collector drives and other electrical equipment.

For numerical program control systems, it is planned to develop technical norm documentation with higher technical requirements (higher reliability, a larger volume of the direct-access memory unit, expanded functional possibilities, smaller size etc.).

The Figure shows the participation of various industries of the national economy in manufacturing machine tools with numerical program control.

One of the sections of program includes a number of norm documents for developing technological processes for series production of standard units and parts of metal-cutting machine tools, as well as documents that determine the technological processes of electrophysical, plasma and ultrasound methods for machining materials difficult to process.

Great attention in the program is devoted to the development of technological norm documents on machining parts on machine tools with ChPU. This should insure efficient operation of such machine tools with the highest productivity.



1. Minstankprom [Ministry of Machine Tool and Tool Industry]
2. Minkhimmash [Ministry of Chemical and Petroleum Machine Building]
3. Minkhimprom [Ministry of Chemical Industry]
4. USSR Minneftekhimprom [Ministry of Petroleum Refining and Petrochemical Industry]
5. Minelektrotekhprom [Ministry of Electrical Equipment Industry]
6. Minavtoprom [Ministry of Automative Industry]
7. USSR Minchermet [Ministry of Ferrous Metallurgy
8. USSR Minugleprom [Ministry of Coal Industry]
9. Minpribor [Ministry of Instrument Making, Automation Equipment and Control Systems

The operation of metal-cutting machine tools and automatic lines is closely tied to the use of auxiliary tools and corresponding cutting tools. Requirements of tools of metal-cutting machine tools are formulated in an independent program "High productivity metal-cutting and auxiliary tools for machine tools with ChPU and automatic lines."

Metrological provision for the production of metal-cutting machine tools specifies a wide use of high productivity and highly accurate universal automated coordinate-measuring machines.

The program includes the development of technical norm documents for regulating the specifics of technical servicing and repairs of metal-cutting machine tools, including those with ChPU.

The unified program "Automated lines, automatic and semiautomatic machines, progressive metal-cutting machine tools for machine building and metal working in 1981-1985," is in functional relationship with a number of unified programs for standardization, developed by the Minstankoprom and other ministries.

The basic purpose of the unified program for standardization of automated lines and metal-cutting machine tools is to provide technical norms to solve the corresponding

scientific technological problem approved by the USSR State Committee on Science and Technology [GKNT]. The successful achievement of the goal, in our opinion, requires a strict tie between the work on solving scientific technological GKNT problems with work on standardization. The unified programs for standardization must be an integral part of solving corresponding problems of GKNT, while those who develop new equipment for unified standardization should have the right to get economic incentives.

The Gosstandart, in developing unified standardization programs, demands absolute positive coordination of all program subjects with basic suppliers of materials, raw materials and complementing products which determine the technical standard of the finished product. However, in most cases, coordination involves great difficulties. In our opinion, for the successful solution of the problem, it will be advisable to give the Gosstandart the right to adopt the final decision when coordinating the unified standardization program.

At present, there is the practice of including in the unified standardization program the development of technical specifications for new equipment needed for the production of concrete finished products. In our opinion, this is unlawful and contradicts GOST 15.001.73 "Development organization of production of products. Basic regulations." Apparently, it is expedient to include technical specifications and the unified standardization program with the following note: "Technical specifications are developed on the condition that all work stages specified by GOST 15.001.73 (order, technical task, technical project etc.) are met.

In conclusion, we will note that the successful realization of the unified standardization program for automated lines and metal-cutting machine tools will make it possible to assimilate in a shorter time the output of high productivity automated metal-cutting machine tools, including those with ChPU, and automated lines for machine building and metal-working in the 11th Five-Year Plan period.

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MICROPROCESSOR MODULE FOR NUMERICALLY CONTROLLED MACHINE TOOLS OUTLINED

Moscow MEKHANIZATSIYA I AVTOMATIZATSIYA PROIZVODSTVA in Russian No 10, 1982 pp 26-27

[Article by V. L. Sosonkin, doctor of technical sciences and V. A. Latyshev, candidate of technical sciences; "Microprocessor Module for Operational Control of Machine Tools with ChPU [Numerical Programed Control] Apparatus"]

[Text] With respect to the representation of the structure of data and algorithms, modern ChPU devices for machine tools may be placed in one of three groups: using apparatus only, using processors only, and using apparatus and processors. In the third group the data structure and algorithms for the ChPU are achieved by a mixed method -- with apparatus and programing which is expedient when modernizing the existing apparatus systems of ChPU by using microprocessor adapters which expand the functional possibilities of the control system by storing complete program texts and editing these texts; by additional "service" to the machine tool operator; and by using effective principles for control. Microprocessor adapters can be located directly in the working zone of the machine tool operator. In this case, the operator introduces the control program manually directly from the drawing of a simple part in the form of a complete text of a previously prepared program, or synthesizes the control program when machining the first part; uses standard cycles, constantly stored in the memory of the microprocessor module etc.

We will consider the technical characteristics of a microprocessor module for a ChPU developed in the form of an adapter to a series manufactured type N-22 ChPU apparatus device. The module is designed as a single-board "Elektronika S5-12" microcomputer. The general ChPU system is shown in Fig. 1, while the panel is shown in Fig. 2 and represents the functional possibilities of the control system as a whole. The mode is the key functional criterion.

The operator panel (Fig. 2) makes it possible to establish one of five modes (keys of field 4, from the top down): work with memory, automatic mode, address input, nondimenisonal travels, adjustment.

In the work with the memory mode, the so-called submodes (keys of field 9) may be selected: preparation of the microprocessor module memory, search for a given frame, instruction by the instruction review of the frame content, editing of frames and individual instructions, introduction of a control program from punched tape, output of the control program on a punched tape in the ISO code. Editing -- is a basic submode; it consists of erasing, replacing or introducing individual instructions or entire frames.

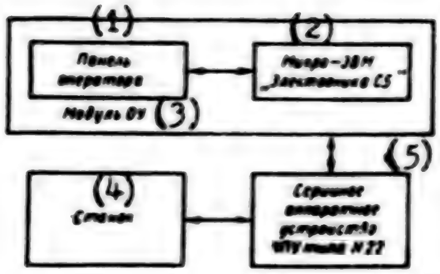

Fig. 1. General configuration of the ChPU system using a microprocessor module and series manufactured ChPU apparatus device.

1. Operator panel
2. "Elektronika S5" microprocessor
3. OU [Terminal] module
4. Machine tool
5. Type N22 series ChPU apparatus device

The control program is finished-off in the automatic mode. This can be done continuously or frame-by-frame, from the first or any other frame, with or without giving control instructions to the feed drives.

The basic operation of the address input mode is introducing a control program frame into an especially assigned area of the microprocessor module memory. The input process is of a dialogue type when the indication lamp lights (Fig. 2) above one or another address indicating to the operator the necessity of a definite data input.

Standard cycles are used in forming frames of the control program. Convenient possibilities are provided to the operator by marks whose coordinates are introduced in the same mode: the marks may be "connected" in any frame by a rectangular cycle. The base points of the corrector table can also be introduced in the address input mode.

In the nondimensional travel mode, the operator controls the carriage and the support of the machine tool, moving the tool in parallel or at an angle of 30, 45 or 60° to the coordinate axes. Moreover, it is possible to introduce the values of the mark and base point coordinates according to the actual position of the tool, and form the frames of the control program on the basis of actual movements with technological additions and corrections.

Instructions (coordinate movements and instructions for addresses F, S, M, T), given in the adjustment mode are executed without being stored in the memory.

Software for the microprocessor module for operating the ChPU may be designed as the translator type. The problem of the module is to translate input instructions, given from the keyboard of the operator's panel, into the language of the type N-22

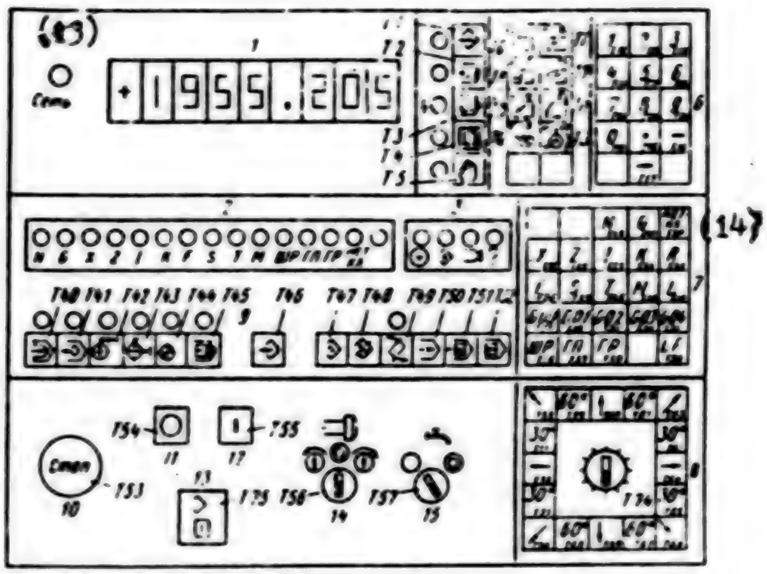

Fig. 2. Operator panel:

1. Digital indications field
2. Dialog indications field
3. Signal indications field
4. Mode controls field
5. Standard cycle control field
6. Digital indications field
7. Symbol data controls field
8. Selection of feed and direction in the mode of nondimensional travels field
9. Submode controls field
10. Emergency stop
11. Stop feed
12. Start feed
13. Network
14. Mark
15. Memory key
16. Spindle drive control
17. Cooling control

TI-T75 -- key designations
ШР -- thread pitch
ГП -- depth of passage
ГР -- depth of thread

ChPU device. The translator development is preceded by an analytical determination of the permitted input instruction circuits in a strict language mode. The well-known Bekus-Naur form is convenient for such determination. The form provides a complex of rules for generating permitted language structures. Each individual rule appears as follows:

< nonterminal symbol > → TERMINAL < circuit of terminals and nonterminal symbols > . A nonterminal symbol is an intermediate variable that serves for the substitution of rules; TERMINAL is a generalized designation of the input library; the circuit of terminals and nonterminal symbols may be vacant; the arrow that separates the right and left parts of the rule is the symbol of generation.

Nonterminal signals are designated α , while the symbols on the keyboard of the operator panel (see Fig. 2) are used for the terminals. The syntax of the input language of the microprocessor module may be described by some set of rules that determine those language instructions which are permitted by control conditions. For example, the address input mode is determined by rules (the vertical dividing line is a symbol for the OR operation):

$\alpha_0 \to$ ADDRESS INPUT α_1 ; $\alpha_1 \to$ KEY α_2 ;

$\alpha_2 \to N\alpha_8\alpha_{10}\alpha_3 \mid T\alpha_9\alpha_{12}\alpha_3 \mid$; Mark $\alpha_7\alpha_{12}\alpha_3$

$\mid$ INITIAL $\alpha_{12}\alpha_3 \mid$; ZERO SHIFT $\alpha_{12}\alpha_2$;
$\alpha_3 \to$ DIGIT α_4 ; $\alpha_4 \to$ DIGIT α_5 $\mid$ ERASE $\alpha_3 \mid$;
$\alpha_5 \to$ DIGIT $\alpha_6 \mid$ ERASE $\alpha_3 \mid$ INPUT etc.

If terminal symbols T shown on the drawing of the operator's panel (see Fig. 2) are used, then the record of the rules will appear as follows:

$$\alpha_0 \to T\,3\,\alpha_1;\ \alpha_1 \to T\,75\,\alpha_2;\ \alpha_2 \to T\,18\,\alpha_8\alpha_{10}\alpha_3 \mid T\,28\,\alpha_9\alpha_{12}\alpha_2 \mid \times$$
$$\times\, T\,20\,\alpha_7\alpha_{12}\alpha_3 \mid T\,44\,\alpha_{12}\alpha_3 \mid T\,43\,\alpha_{12}\alpha_2;\ \alpha_3 \to T\,14\,\alpha_4;$$
$$\alpha_4 \to T\,14\,\alpha_5 \mid T\,47\,\alpha_3 \mid T\,46;\ \alpha_5 \to T\,14\,\alpha_6 \mid T\,47\,\alpha_3 \mid T\,46;$$
$$\alpha_6 \to T\,47\,\alpha_3 \mid T\,46;\ \alpha_7 \to T\,14\,\alpha_8;\ \alpha_8 \to T\,14\,\alpha_9 \mid T\,47\,\alpha_7 \mid T\,46;$$
$$\alpha_9 \to T\,47\,\alpha_8 \mid T\,46;\ \alpha_{10} \to T\,19\,\alpha_7\alpha_{11}\alpha_{43} \mid T\,31\,\alpha_{12}\alpha_{42} \times$$
$$\times \mid T\,32\,\alpha_{12}\alpha_{21}\alpha_{31}\alpha_{43} \mid T\,33\,\alpha_{12}\alpha_{35}\alpha_{33}\alpha_{21}\alpha_{42} \mid T\,34\,\alpha_{12}\alpha_{32} \times$$
$$\times\, \alpha_{33}\alpha_{21}\alpha_{42} \mid T\,35\,\alpha_{34}\alpha_{42} \mid T\,6\,\alpha_{12}\alpha_{35}\alpha_{21}\alpha_{42} \mid T\,7\,\alpha_{12}\alpha_{36} \times$$
$$\times\, \alpha_{21}\alpha_{42} \mid T\,8\,\alpha_{12}\alpha_{38}\alpha_{35}\alpha_{21}\alpha_{42} \mid T\,9\,\alpha_{12}\alpha_{39}\alpha_{35}\alpha_{21}\alpha_{42} \times$$
$$\times \mid T\,10\,\alpha_{38}\alpha_{21}\alpha_{43} \mid T\,11\,\alpha_{38}\alpha_{21}\alpha_{42} \mid T\,12\,\alpha_{12}\alpha_{37}\alpha_{33}\alpha_{35}\alpha_{21} \times$$
$$\times\, \alpha_{42} \mid T\,13\,\alpha_{39} \mid T\,17\,\alpha_{60};\ \alpha_{11} \to T\,31\,\alpha_{12}\alpha_{43} \mid T\,32\,\alpha_{12}\alpha_{21} \times$$
$$\times\, \alpha_{31}\alpha_{42} \mid T\,33\,\alpha_{12}\alpha_{38}\alpha_{21}\alpha_{43} \mid T\,34\,\alpha_{12}\alpha_{33}\alpha_{38}\alpha_{21}\alpha_{42} \times$$
$$\times \mid T\,35\,\alpha_{34}\alpha_{43} \mid T\,6\,\alpha_{12}\alpha_{35}\alpha_{21}\alpha_{43} \mid T\,7\,\alpha_{12}\alpha_{36}\alpha_{21}\alpha_{43} \mid T\,8\,\alpha_{12} \times$$
$$\times\, \alpha_{38}\alpha_{39}\alpha_{21}\alpha_{42} \mid T\,9\,\alpha_{12}\alpha_{39}\alpha_{35}\alpha_{21}\alpha_{42} \mid T\,10\,\alpha_{38}\alpha_{21}\alpha_{42} \times$$
$$\times \mid T\,11\,\alpha_{38}\alpha_{21}\alpha_{43} \mid T\,12\,\alpha_{12}\alpha_{37}\alpha_{38}\alpha_{35}\alpha_{21}\alpha_{43} \mid T\,13\,\alpha_{39};$$
$$\alpha_{12} \to T\,21\,\alpha_{13}\alpha_{20} \mid T\,17\,\alpha_{20};\ \alpha_{13} \to T\,16\,\alpha_{14} \mid T\,15\,\alpha_{16} \mid T\,14\,\alpha_{16};$$
$$\alpha_{14} \to T\,15\,\alpha_{16} \mid T\,14\,\alpha_{16} \mid T\,47\,\alpha_{18};\ \alpha_{15} \to T\,14\,\alpha_{17} \mid T\,47\,\alpha_{13};$$
$$\alpha_{16} \to T\,15\,\alpha_{18} \mid T\,14\,\alpha_{18} \mid T\,47\,\alpha_{13} \mid T\,46;\ \alpha_{17} \to T\,14\,\alpha_{17} \times$$
$$\times \mid T\,47\,\alpha_{13} \mid T\,46;\ \alpha_{18} \to T\,14\,\alpha_{17} \mid T\,47\,\alpha_{13} \mid T\,46;\ \alpha_{19} \to T\,47;$$
$$\alpha_{20} \to T_{22}\,\alpha_{18} \mid T\,17;\ \alpha_{21} \to T\,26\,\alpha_{23}\alpha_{28}\alpha_{29}\alpha_{30} \mid T\,17\,\alpha_{28}\alpha_{29}\alpha_{30};$$
$$\alpha_{23} \to 14\,\alpha_{33};\ \alpha_{33} \to T\,14\,\alpha_{34} \mid T\,47\,\alpha_{23}\ldots$$

Following the same principles, rules can be prepared for the remaining modes. The substition of the rules of one into the other leads to the right part of the transformed rule changing to a circuit consisting only of terminals which will indicate one possible version of interaction between the operator and the control panel. No other control versions, except those provided by the substitutions of rules, exist. The indicated rules are useful, not only for developing software of the translator type for the microprocessor module, but also for the formal assignment of interaction methods between the operator and the control panel which is briefer and more exact than the disordered word descriptions accepted in technical manuals for control systems.

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SYNTHESIS OF AUTOMATIC MANIPULATOR MOVEMENTS DISCUSSED

Moscow MEKHANIZATSIYA I AVTOMATIZATSIYA PROIZVODSTVA in Russian No 10, Oct 82 pp 13-19

[Article by V. F. Krasnikov, candidate of technical sciences: "Synthesis of Automatic Manipulator Structure."]

[Text] The synthesis of an automatic manipulator (AM) is the design of its structural arrangement, by which is meant the manipulator arrangement which includes the stand, movable links, kinematic couple types and their mutual configuration. The synthesis of the structure made at the earliest stages of the AM design by utilizing formalized mathematical methods, is characterized by a limited number of initial data and the necessity of using formalized heuristic methods, and optimization methods. At present, synthesis attempts are made based upon a number of possible structural versions with a limited number of links and kinematic couples.

This article describes a numerical engineering method for synthesizing the structure of manipulators, based on subdividing a given number of degrees of mobility W into a set of non-negative integers, whose values define the mobility of kinematic couples P, while their number defines a number of links S of the kinematic circuit of the manipulator. The method is simple to apply and has no limitations because of the complexity of the kinematic circuit of the manipulator. One of the most important parameters that characterizes the AM is the number of degrees of mobility W which is assigned when they are created. We will assume that the value of W is a basic condition of synthesis.

For AM with a spatial and open kinematic circuit, W is calculated by the following relationship:

$$W = p_5 + 2p_4 + 3p_3 + 4p_2 + 5p_1. \qquad (1)$$

where p_5, p_4, p_3, p_2, p_1 are the number of couples of one-, two-, three-, four-, and five-degrees of mobility. In manipulators with open kinematic circuits, the number of mobile lines n is equal to the number of kinematic couples.

The synthesis is made on the basis of the known theorem that the number of degrees of mobility is equal to the sum of the mobilities of kinematic couples. Let W=6 be given. We will syntheize the AM structure according to the algorithm.

Determination of classes of couples used in the kinematic circuit. Manipulators use widely kinematic pairs p_5, p_4 and p_3 that have degrees of mobilities equal respectively to $W_p = 1, 2, 3$. Therefore, we assume that couples of these three classes are used in the synthesized AM circuit.

Subdivision of the given number W into finite set of non-negative numbers whose sum is equal to W. We will subdivide number W=6 into the following alternative finite set of numbers.

$$\begin{gathered} a)\ 6=1+1+1+1+1+1; \quad b)\ 6=1+1+1+1+2; \\ c)\ 6=1+1+1+3; \quad d)\ 6=1+1+4; \quad e)\ 6=1+5; \\ f)\ 6=1+2+3; \quad g)\ 6=1+1+2+2; \quad h)\ 6=2+2+2; \\ i)\ 6=3+3; \quad j)\ 6=2+4. \qquad (2) \end{gathered}$$

Thus, the given number W=6 may be represented in the form $N(\rho)=10$ subdivisions or sets of non-negative integers.

Selection of realized subdivisions. Since only kinematic couples p_5, p_4 and p_3 are used in the kinematic circuit of the manipulator, those should be selected from the alternative set of subdivisions that contain digits not greater than 3. Thus, realizable subdivisions are: a, b, c, f, g, h, i. Realizable subdivision a defines a uniform kinematic manipulator circuit with only single-degree mobility p_5 couples; subdivision b -- a circuit which, besides single-degree mobility couples, contains two two-degree mobility couple p_4; subdivision c -- a circuit which contains three-degree mobility couple p_3; subdivision f -- a circuit which contains one each of a single-, two- and three-degree mobility couples; subdivision g -- a circuit which contains two each of single-degree mobility and two two-degree mobility couples; subdivision h -- a uniform circuit which contains only two-degree mobility couples; subdivision i -- a uniform circuit with only three-degree mobility couples. Thus, there are only seven realizable couples of ten alternative subdivisions.

Determination of basic parameters of the manipulator structure. The number of integers $q \in Q$ in subdivisions is identical to the number (set) of kinematic couples $p^n \in P$ in the structure of the represented AM circuit. The value of the individual numbers in the subdivisions correspond to the degrees of mobility of the kinematic couples. The number (set) of links S is determined from an expression true only for open kinematic circuits

$$S = P - 1. \qquad (3)$$

Any manipulator structure consists of two basic components: a finite set of kinematic couples P and a finite set of links S. The analytical structure of AM is described by set ρ (P, S). Value P, which describes the number of kinematic couples, is also the order of the manipulator structure. For closed kinematic

circuits containing only one closed loop between sets P and S there is identity

$$P = S. \qquad (4)$$

If, however, the closed circuit contains more than one closed loop, then

$$P < S. \qquad (5)$$

Thus, by subdivisions, it is possible to identify (establish) fully the general form of the AM structure. The realizable subdivisions of the manipulator structures can be written analytically in the form of sets: a) $\rho_a(6,5)$, b) $\rho_b(5,4)$, c) $\rho_c(4, 3,)$ f) $\rho_f(3, 2)$, g) $\rho_g(4, 3)$, h) $\rho_h(3, 2)$ and i) $\rho_i(2, 1)$. Taking into account the kinematic classes and the ties between them, these subdivisions may be rewritten in a more detailed form:

$$\text{a)}\ \rho_a\{P(p_5^1, p_5^2, \ldots, p_5^6), S(s_{32}, s_{33}, \ldots, s_{66})\};$$
$$\text{b)}\ \rho_b\{P(p_5^1, p_5^2, p_5^3, p_5^4, p_4^5), S(s_{31}, s_{32}, s_{43}, s_{54})\};$$
$$\text{c)}\ \rho_c\{P(p_5^1, p_5^2, p_5^3, p_5^4), S(s_{21}, s_{32}, s_{43})\};$$
$$\text{f)}\ \rho_f\{P(p_5^1, p_4^2, p_3^3), S(s_{21}, s_{32})\};$$
$$\text{g)}\ \rho_g\{P(p_5^1, p_5^2, p_4^3, p_4^4), S(s_{21}, s_{32}, s_{43})\};$$
$$\text{h)}\ \rho_h\{P(p_4^1, p_4^2, p_4^3), S(s_{21}, s_{32})\};$$
$$\text{i)}\ \rho_i\{P(p_3^1, p_3^2), S(s_{21})\}.$$

Analysis of alternate versions of the structural arrangements of the manipulator. The number of alternative variations ν of the structural arrangements, corresponding to each realizable subdivision is increased according to the varieties of kinematic couples. Thus, single-degree mobility couple p_5 has three varieties $\nu_{p_5}=3$: rotational -- r_{p_5}; stepping -- s_{p_5} and helical -- h_{p_5}; two-degree mobility couple p_4 has two versions: $\nu_{p_4}=2$: cylindrical -- c_{p_4} and spherical with a finger -- s_{p_4}. The three-degree mobility couple also has two versions: $\nu_{p_3}=2$: spherical -- s_{p_3} and planar -- p_{p_3}. The number of variations of structural arrangements is equal to the number of dispositions A_m^n of $m=\nu$ of couple varieties of $n=P$.

$$v = A_m^n = v(v-1)(v-2)\ldots[v-(P-1)]. \qquad (6)$$

For example, in realizable subdivision f, which contains single-degree mobiliy p_5, two-degree mobility p_4 and three -degree mobility p_3 couples, the number of versions due to varieties of all couples is

$$v_p = v\,p_5 + v\,p_4 + v\,p_3 = 3 + 2 + 2 = 7$$

equal respectively to

$$v = A_7^3 = 7\,(7-1)\,(7-2) = 210.$$

Along with this, the considerable diversity of kinematic circuit versions is due to the change in the mutual transposition of the adopted nomenclature of the couple. By transposing couples, various versions of the kinematic circuits are obtained which determine the structural formulation, ease of manufacture and reliability of the manipulators. The total number of possible transpositions of P couples is equal to

$$v_p = P\,!. \qquad (7)$$

For example, the number of versions of kinematic arrangements in the subdivision of f due to the transposition of couples p_5, p_4 and p_3 is equal to

$$v_P = 3! = 1 \times 2 \times 3 = 6,$$ i.e., 1) $p_5\ p_4\ p_3$; 2) $p_5\ p_3\ p_4$; 3) $p_4\ p_5\ p_3$; 4) $p_4\ p_3\ p_5$; 5) $p_3\ p_5\ p_4$; 6) $p_3\ p_4\ p_5$.

Taking into account the varieties of pairs, the number of versions of arrangements increases sharply.

However, not all possible kinematic versions of arrangements are adequate. Therefore, in selecting the most optimal version, it is necessary to take into account additional conditions of synthesis.

The additional conditions of synthesis or limitations at this stage and the limiting values of AM criteria and characteristics are given: maneuverablility μ, working volume V_p, working zone F_p, angle ψ and service coefficient C_ψ, structural reliability $H\left[\rho\right]$ and structural complexity ζ. We will consider one of the entire diversity of conditions and limitations, characteristic of this stage, -- the structural complexity.

Usually, the structural complexity of AM is evaluated intuitively. With such an evaluation, the actual complexity of the structure is not always determined objectively. Therefore, it appears urgent to establish quantitative criteria for evaluating the complexity of the AM structure. The complexity of the structure

is determined by the complexity, types and number of components: kinematic pairs

$$P = \{ P_C^1 P_m^2, \ldots, P_k^n \}.$$

link S and the number of degrees of mobility W.

We will assume conditionally that the structural complexity of kinematic couples P_5, P_4, P_3, P_2, P_1 is identical to their mobility, i.e.,

$$\zeta_{p_5} = 1,\ \zeta_{p_4} = 2,\ \zeta_{p_3} = 3,\ \zeta_{p_2} = 4,\ \zeta_{p_1} = 5.$$

The structural complexity of the mutual relation is evaluated by $\zeta_s = 1$, if the axes of the kinematic couples are parallel; if the axes are perpendicular or at an angle to each other, then $\zeta_s = 2$.

The complexity of the structure or the structural complexity of AM is relationship

$$\zeta(\rho) = \frac{\sum_{i=1}^{i=P} \zeta_p^i + \sum_{i=1}^{i=s} \zeta_s^i + W}{3}, \qquad (8)$$

where

$$\sum_{i=1}^{i=P} \zeta_p^i$$

is the structural complexity of all kinematic couples that form the kinematic circuit;

$$\sum_{i=l}^{i=s} \zeta_l^s$$

is the structural complexity of the links that connect the kinematic couples; W is the number of degrees of mobility of AM. The structural complexity of the initial link of AM formed by a one-degree mobility couple and mobile link $p_5=1$, which represents a plane mechanism of the first class, that has W=1, is equal to

$$\zeta[\rho(P,S)] = \zeta[\rho(1,1)] = \frac{\rho_k S + W}{3} = \frac{1+1+1}{3} = 1.$$

Using formula (8) and assuming that the axes of the couples are parallel, we will determine the structural complexity of the AM of the presented realizable subdivisions:

$$\text{a) } \zeta_a[\rho(6,5)] = \frac{17}{3}; \quad \text{b) } \zeta_b[\rho(5,4)] = \frac{16}{3};$$
$$\text{e) } \zeta_c[\rho(4,3)] = \frac{15}{3}; \quad \text{f) } \zeta_f[\rho(3,2)] = \frac{14}{3};$$
$$\text{g) } \zeta_g[\rho(4,3)] = \frac{15}{3}; \quad \text{h) } \zeta_h[\rho(3,2)] = \frac{14}{3};$$
$$\text{i) } \zeta_i[\rho(2,1)] = \frac{13}{3}. \qquad (9)$$

Thus, kinematic circuit AM ρ_a (6.5) has a greatest structural complexity

$$\zeta_a = \frac{17}{3}$$

and a least -- $\rho_i(2,1)$ -- $\zeta_i = \frac{13}{3}$.

From the values obtained, an AM structure is selected that has a satisfactory structural relationship simultaneously observing other additional conditions of synthesis and limitations.

Graphic plotting of manipulator kinematic arrangements. Based on the selected versions of the realizable subdivisions, a graphic representation of the AM structure is made. Thus, a logical transition is made from an analytical to a graphic representation of the structure. For this purpose of system analysis of all or the majority of the alternatives of AM kinematic circuits, it is sound practice, like the duplicating structures of metal-cutting machine tools, to make graphic representations of a generalized kinematically possible nomenclature of the structure of the circuit (Fig. 1). Vertical lines I, II...N represent the axes or steps of kinematic couples whose number is equal to a set of couples or digits in the realizable subdivision. The horizontal lines represent a generalized set of types and variations of kinematic couples. Each line represents one kind of

couple. The point of intersection of the vertical and horizontal line corresponds to the position of the kinematic couple on a given axis. If, on a given axis, there is no kinematic couple, there is no point of intersection and the horizontal line is traced farther to the intersection of that vertical line for which a couple is provided.

Using the realizable versions of subdivisions (2) and the generalized structure, the nomenclature of the kinematic couples is determined and the structural arrangements of AM are plotted (Fig. 2). By calculating by formula (1) and checking the synthesis thereby, it is possible to make sure that all seven versions of the structures meet the basic conditions of the synthesis, i.e., obtain a given number of degrees of mobility W=6 is possible.

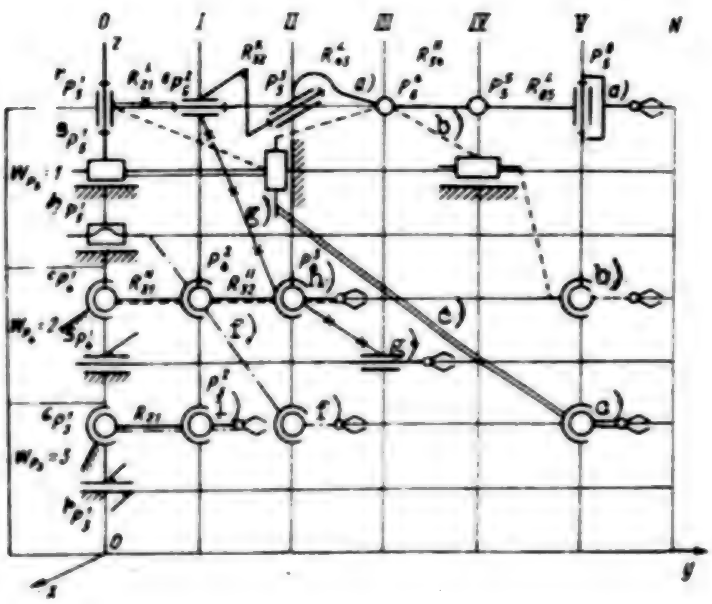

Fig. 1. Generalized structure of automatic manipulators

Determination of mutual orientation of kinematic couples. The mutual location and orientation of the axes of kinematic couples and the nature of the relations between them affect greatly many kinematic, dynamic characteristics and parameters of the AM synthesis: maneuverability, the value of working volume, the servicing zone, the angle and coefficient of service, as well as the type of circuit -- plane or spatial etc. Therefore, after determining the nomenclatures of the couples and the general structural AM arrangement, an orientation is made of the axes of the couples in space. The mutual positioning of adjacent couples P_1^1, $P_m^1 \in P$ we will represent analytically in the form of R_{j1} relationships.

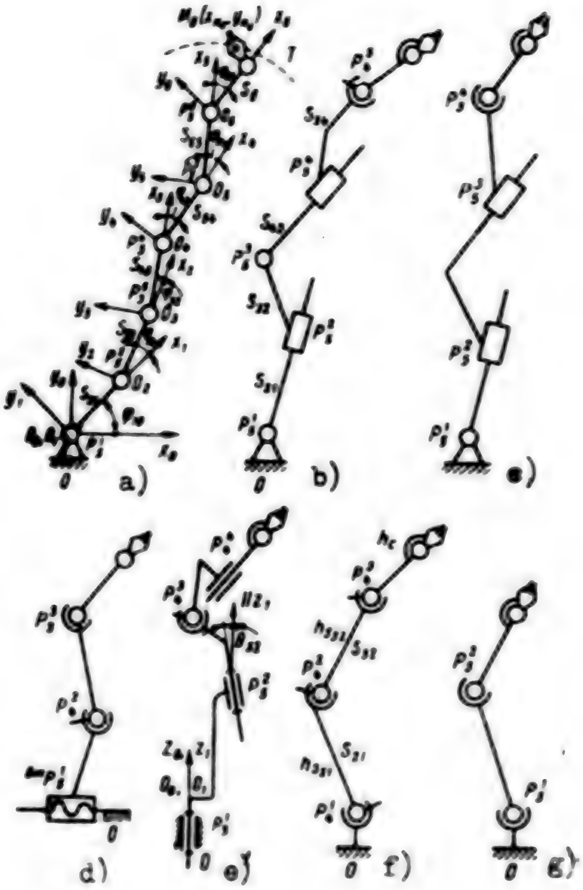

Fig. 2. Version of automatic manipulator structures

Basic types of mutual positioning of one-degree mobility couple axes are: parallel $R^{\parallel}_{ji}$, perpendicular $R^{\perp}_{ji}$, crossing $R^{\times}_{ji}$, crossing at a random angle $R^{<}_{ji}$. It is expedient to orient axes of one-degree mobility couples in space parallel to the XYZ coordinate axes. In this case if, for example, axis of couple $p^i_l \in P$ is parallel to axis Z, while the axis of couple p^j_m P adjacent to it is parallel to axis Y, then their mutual disposition is described by relationship p^i_l, $R^{\perp}_{ji}$, p^j_m. If, however, the axis of couple p^p_k is parallel to axis X, then the mutual disposition of adjacent couples p^i_l, $p^n_k \in P$ is described by relationship p^i_l, R_{ni}, p^n_k. When using two-degree mobility cylindrical couples ${}^c p_4$, their axes are oriented in

the same way as of the one-degree mobility couples. In two-degree mobility spherical couples, the orientation is made with respect to the axis of the finger. Relationships R_{j1} between couples are mathematically described by analytical geometry methods.

Various orientations and dispositions of couples result in an increased number of variations in structural arrangements, for example, variation a of the realizable subdivision provides a number of versions of structural AM arrangements, some of which are described in the form of relationships

$$
\begin{aligned}
&\text{A. } [P_5^1 R_{21}^{\perp} P_5^2 R_{32}^{\times} P_5^3 \overline{R_{43}^{\leq} P_5^4} R_{54}^{\parallel} P_5^5 \overline{R_{65}^{\perp}} P_5^6].\\
&\text{B. } [P_5^1 R_{21}^{\times} P_5^2 R_{32}^{\parallel} P_5^3 R_{43}^{\perp} P_5^4 R_{54}^{\times} P_5^5 R_{65}^{\parallel} P_5^6].\\
&\text{C. } [P_5^1 R_{21}^{\leq} P_5^2 R_{32}^{\parallel} P_5^3 R_{43}^{\perp} P_5^4 R_{54}^{\leq} P_5^5 R_{65}^{\times} P_5^6].
\end{aligned}
\tag{10}
$$

The obtained versions in structural arrangements differ considerably from each other with respect to kinematic and dynamic characteristics.

Selection of structural arrangement and calculation of the parameters of synthesis. From the obtained versions and varieties of structural arrangements, a selection is made of a version that satisfies the given requirements and concrete conditions most fully. The selection is made with the simultaneous calculation of synthesis parameters, taking into account limitations and additional conditions which are expressed by inequalities that establish permitted areas of existence of the parameters.

To provide high reliability of the AM at the design stage of its structural arrangements, it is necessary to obtain high structural reliability $H[\rho(P, S)]$. In this case, the rated structural reliability $H^p[\rho(P\ S)]$ must be not less than the previously determined

$$H^p[\rho(P, S)] \geq H[\rho(P, S)]. \tag{11}$$

We will formulate the reliability function for two versions of the obtained structures

$$H_a^p[\rho(6,5)] = h_{p_a}^6 h_{s_{21}} h_{s_{32}} h_{s_{43}} h_{s_{54}} h_{s_{65}} h_c. \tag{12}$$

$$H_c^p\,[\rho\,(3,2)] = h_{p_4}^3\, h_{s_{21}}\, h_{s_{32}}\, h_c. \qquad (13)$$

where h_{p_5}, h_{p_4} -- reliabilities of kinematic couples of the fifth and fourth classes respectively; $h_{s_{21}}$, $h_{s_{32}}$, $h_{s_{65}}$ -- reliability of AM links; h_c -- reliability of grip. Assuming,

$$h_{s_{21}} = h_{s_{32}} = \ldots = h_{s_{65}} = h_s;\; h_{p_5} \simeq h_{p_4}^3;\; h_{p_3} \simeq h_{p_4}^2,$$

we will write reliability functions (12) and (13) in the form of polynomials

$$H_a^p\,[\rho\,(6,5)] = h_{p_4}^6\, h_s^5\, h_c. \qquad (14)$$

$$H_h^p\,[\rho\,(3,2)] = h_{p_4}^6\, h_s^2\, h_c. \qquad (15)$$

Comparing expressions (14) and (15), for all other conditions being equal, we find that $H_a^P < H_h^P$. Assuming conditionally

$$h_{p_4} = 0{,}99;\; h_s = 0{,}999;\; h_c = 0{,}99,$$

we will obtain numerical values for the structural reliability of the versions of the AM structure being compared

$$H_a^p\,[\rho\,(6,5)] = h_{p_4}^6\, h_s^5\, h_c = 0{,}99^6 \cdot 0{,}999^5 \cdot 0{,}99 \simeq 0{,}91; \quad (16)$$

$$H^p\,[\rho\,(3,2)] = h_{p_4}^6\, h_s^2\, h_c = 0{,}99^6 \cdot 0{,}999^2 \cdot 0{,}99 \simeq 0{,}93. \quad (17)$$

By analyzing all the obtained AM structures for assumed equal values of h_{p_5}, h_s, h_c, we find that the version shown in Fig. 2a has the least structural reliability H_{min}^P. The versions shown in Fig. 2б has the greatest reliability H_{max}^P. Thus,

(11) will assume form

$$H^{p}_{min} = 0.91 > H^{v}.$$

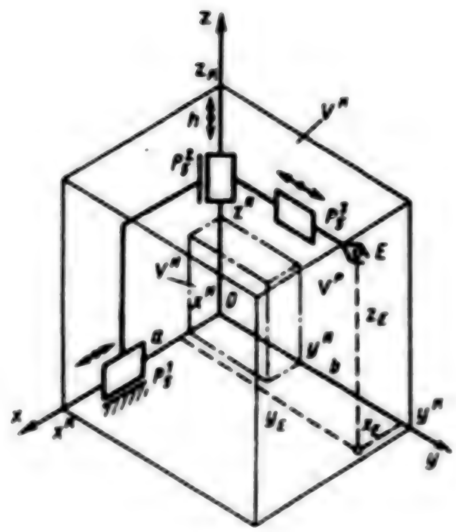

Fig. 3. Arrangement of a three-degree mobility automatic manipulator operating in a rectangular system of coordinates.

To provide for given values of working volume V^3_p, servicing zone F^3, angle ψ^3 and service coefficient C^3_{ψ}, it is required that:

$$V^p_p > V^з_p;\ F^p > F^з;\ \psi^p > \psi^з;\ C^p_{\psi} > C^з_{\psi}. \quad (18)$$

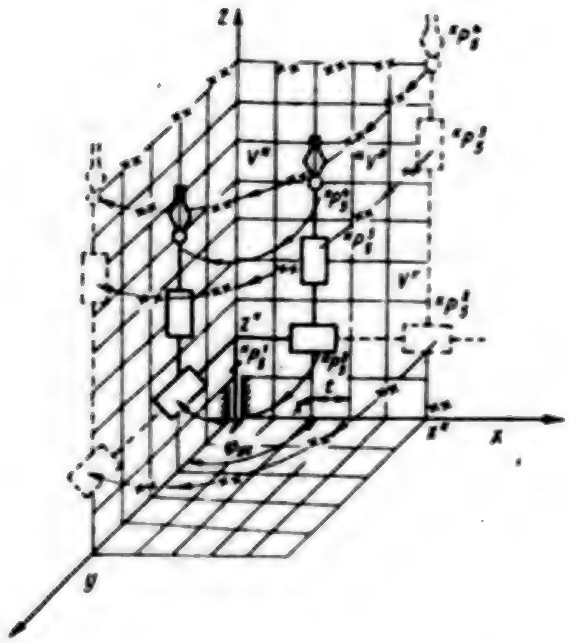

Fig. 4. Coordinate grid for determining motions of the grip.

where V_p^p, F^p, ψ^p and C_γ^p are the rated values of the working volume, servicing zone, angle and service coefficient.

The shape and configuration of working zone V_p are determined by the system of coordinates in which the AM operates. The working zone of an AM functioning in a rectangular system of coordinates has the shape of a parallelepiped (Fig. 3). If initial coordinates are given

$$\vec{a}_1^{н}\{x_1^{н}, y_1^{н}, z_1^{н}\}, \vec{a}_2^{н}\{x_2^{н}, y_2^{н}, z_2^{н}\}, \vec{a}_3^{н}\{x_3^{н}, y_3^{н}, z_3^{н}\}$$

and final coordinates

$$\vec{a}_1^{к}\{x_1^{к}, y_1^{к}, z_1^{к}\}, \vec{a}_2^{к}\{x_2^{к}, y_2^{к}, z_2^{к}\}, \vec{a}_3^{к}\{x_3^{к}, y_3^{к}, z_3^{к}\}$$

of vectors that determine the position of the grip, then working zone V_p of the manipulator is determined from expression

$$V_p = \begin{vmatrix} x_1^k & y_1^k & z_1^k \\ x_2^k & y_2^k & z_2^k \\ x_3^k & y_3^k & z_3^k \end{vmatrix} - \begin{vmatrix} x_1^H & y_1^H & z_1^H \\ x_2^H & y_2^H & z_2^H \\ x_3^H & y_3^H & z_3^H \end{vmatrix}. \qquad (19)$$

The working zone, in the case of an occupied space, is reduced by values corresponding to the volume occupied by a solid, a device or other obstacles.

Working volume ${}^{c}V_p$ of an AM, operating in the cylindrical system of coordinates, may be found as the difference of volumes, described by a set of grip positions in the final V^k and initial V^H positions (Fig. 4)

$${}^{c}V_p = V^k - V^H.$$

The value of the grip movements along the coordinate axis and in working volume Vp is an important criterion that characterizes the working zone of the AM. We will impose a coordinate grid on planes XOZ, YOZ and XOY with a pitch t=1 between nodes. Full maximal movement of the grip is determined from expression

$$l_{ij} = (x_i^k - x_i^H) + (y_i^k - y_i^H) + (z_i^k - z_i^H). \qquad (20)$$

where x_1^H, y_1^H, z_1^H -- initial coordinates; k_1^k, y_1^k, z_1^k -- the final coordinates of the grip.

The dimensions of the coordinate grid are given in the form of a product kxmxn, where k, m, n -- number of nodes respectively along axes X, Y, Z. For AM (see Fig. 4) movements of the grip along axes X and Z in plane XOZ are determined from expression

$$l_{ij} = (x_i^k - x_i^H) + (z_i^k - z_i^H) = (5-2) + (9-6) = 6.$$

Kinematic couple ${}^{H}p_5^1$ provides for turning the AM by an angle φ_{5A} and moving it from plane XOZ to plane YOZ.

Full motion of the grip, kinematic couples and links are represented in the form of a movement matrix $L = \|l_{ji}\|k \times m \times n$, composed by rule:

$$l_{ij} = \begin{cases} 0, & \text{if} \quad x^a > x^b,\ y^a > y^b,\ z^a > z^b, \\ k,\ m,\ n, & \text{if} \quad x^a = x^b,\ y^a = y^b,\ z^a = z^b; \end{cases}$$

For the AM (see Fig 4) matrix L has the form

$$\begin{array}{c|cccc|c} & p_5^1 & p_5^2 & p_5^3 & p_5^4 & \sum\limits_{\substack{j=1 \\ i=\text{const}}} l_{ji} \\ p_5^1 & 0 & 3 & 6 & 6 & 15 \\ p_5^2 & & 0 & 3 & 3 & 6 \\ p_5^3 & & & 0 & 0 & 0 \\ p_5^4 & & & & 0 & 0 \\ & & & & & \Sigma\Sigma\, l_{ij} = 21 \end{array} \qquad (21)$$

The sum of elements

$$\sum_{j=1}^{4} l_{ij} = 15$$

in matrix (21) represents the full motion of the grip in the first line with respect to couple p_5^1; in the second line $\sum l_{24} = 6$ -- the motion with respect to couple p_5^2 and, finally, in the third -- with respect to couple p_5^3. The sum of all elements

$$\sum_{\substack{i=1 \\ j=\text{const}}} \sum_{\substack{j=1 \\ i=\text{const}}} \times\ l_{ji} = 21$$

represents the full motion of the grip. By preparing matrices L for all compared versions of AM structures, it is possible to obtain unit values for grip motions and select the optimal version objectively.

Providing high maneuverability of the AM. The maneuverability and universality of the grip kinematics depend on the diversity of the AM structure; class, type, number of kinematic couples, mutual orientation of their axes and link parameters. Structural diversity $g[\rho(P, S)]$ of the manipulator is evaluated quantitatively by

a square matrix of contiguity G, prepared according to the following rule:

1, if j -- kinematic couple p_m^j differs from p_1^i in class, type and mutual orientation of the axis in space;

0, if the enumerated differences are absent.

We will prepare matrices G_a and G_b for sturctural versions (see Fig. 2a) and (see Fig. 2b)

$$G_a = \begin{vmatrix} 1 & 1 & 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 1 & 1 & 1 \\ 0 & 1 & 1 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 1 & 1 & 0 \end{vmatrix}, \quad G_b = \begin{vmatrix} 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{vmatrix}.$$

Having calculated G_a and G_b, we find $G_b < G_a$. Therefore, the structural diversity and consequently the maneuverability and universality of manipulator kinematics $\rho(5, 4)$ (see Fig. 2b) is considerably higher than that of manipulator $\rho(6.5)$ (see Fig. 2a).

Limitations in the length of the links are set in the form of permitted intervals, depending upon their design.

In order that there be no lengths of links s_{21}, s_{32}, ... s_n, n-1 that are too large or too small, their lengths are selected so that

$$s_{min} \leq s_{21} \leq s_{32} \leq \ldots \leq s_{max}, \quad \frac{s_{max}}{s_{min}} \leq K. \qquad (22)$$

Then not one of the lengths of the links will exceed another by more than K times in all combinations. Limitations on weight m_{ij} and moments of inertia J_{ji} are obtained from these intervals since, for a certain link length, its weight and moment of inertia may be made within certain limits.

The graphic presentation of versions on a generalized plane (see Fig. 1), besides a visual and systematic review of all possible structural arrangements or the majority of structural arrangements, makes it possible to describe them analytically in the form of proximity matrices, incidence, relationships, system of algebraic equations etc. For example, version b in the form of a relationship matrix will be represented by (see Fig. 2b)

$$
I_6 = \begin{array}{c} \\ p_5^1 \\ p_5^2 \\ p_5^3 \\ p_5^4 \\ p_4^5 \end{array}
\begin{array}{c} \begin{array}{ccccc} p_5^1 & p_5^2 & p_5^3 & p_5^4 & p_4^5 \end{array} \\
\left|\begin{array}{ccccc}
1 & & & & \\
R_{21}^{\perp} & 1 & & & \\
 & R_{32}^{\times} & 1 & & \\
 & & R_{43}^{\perp} & 1 & \\
 & & & R_{54}^{<} & 1
\end{array}\right| \end{array}. \qquad (23)
$$

Mathematical representations of structural arrangements are needed to carry out subsequent kinematic and dynamic syntheses of the AM and the synthesis of its control system.

The calculation of the basic parameters of the synthesis is made on the basis of the function of the AM and those programed motions which must be made by the grip. It is expedient to program the motions in the form of a typical analytical relationship which is the system function of synthesis

$$T = T(|p(P, S)|q)$$

and represents trajectory T of grip motion (see Fig. 2a).

The basic parameters of the AM synthesis (see Fig. 2a) are: dimensions of links s_{21}, s_{32}, s_{43}, s_{54}, s_{65}; coordinates of some point M_6 (x_{m_6}, y_{m_6}), for example, the center of gravity of the product or grip in the $O_6\, x_6\, y_6$ system of coordinates tied to link s_6; angles

$$\theta_{21}, \theta_{32}, \theta_{43}, \dot{\theta}_{54}, \theta_{65}$$

between axes O_j and O_i of adjacent kinematic couples

$$p_5^1, p_5^2, p_5^3, p_5^4, p_5^5, p_5^6$$

Fig. 2a, e).

To calculate the parameters of the synthesis, it is necessary to represent the data for grip parameters in the coordinate form. For manipulator ρ (6,5) (see Fig. 2a), the system of linear equations that determines the position coordinates of links and kinematic couples, has the form

$$\text{a)}\quad \left.\begin{aligned} x_{m_5} &= x_{m_6}\cos\varphi_{65} - y_{m_6}\sin\varphi_{65} + s_{65} \\ y_{m_5} &= x_{m_6}\sin\varphi_{65} + y_{m_6}\cos\varphi_{65} \end{aligned}\right\}.$$

$$\text{b)}\quad \left.\begin{aligned} x_{m_4} &= x_{m_5}\cos\varphi_{54} - y_{m_5}\sin\varphi_{54} + s_{54} \\ y_{m_4} &= x_{m_5}\sin\varphi_{54} + y_{m_5}\cos\varphi_{54} \end{aligned}\right\}.$$

$$\text{c)}\quad \left.\begin{aligned} x_{m_3} &= x_{m_4}\cos\varphi_{43} - y_{m_4}\sin\varphi_{43} + s_{43} \\ y_{m_3} &= x_{m_4}\sin\varphi_{43} + y_{m_4}\cos\varphi_{43} \end{aligned}\right\}.$$

$$\text{d)}\quad \left.\begin{aligned} x_{m_2} &= x_{m_3}\cos\varphi_{32} - y_{m_3}\sin\varphi_{32} + s_{32} \\ y_{m_2} &= x_{m_3}\sin\varphi_{32} + y_{m_3}\cos\varphi_{32} \end{aligned}\right\}.$$

$$\text{e)}\quad \left.\begin{aligned} x_{m_1} &= x_{m_2}\cos\varphi_{21} - y_{m_2}\sin\varphi_{21} + s_{21} \\ y_{m_1} &= x_{m_2}\sin\varphi_{21} + y_{m_2}\cos\varphi_{21} \end{aligned}\right\}.$$

e

$$\text{f)}\quad \left.\begin{aligned} x_{m_0} &= x_{m_1}\cos\varphi_{10} - y_{m_1}\sin\varphi_{10} \\ y_{m_0} &= x_{m_1}\sin\varphi_{10} + y_{m_1}\cos\varphi_{10} \end{aligned}\right\}. \qquad (24)$$

where x_{m_6}, y_{m_6} -- coordinates of some point M_6 (for example, the center of gravity of the product or the center of the grip);

$$x_{m_5},\ y_{m_5},\ x_{m_4},\ y_{m_4},\ x_{m_3},\ y_{m_3},\ x_{m_2},\ y_{m_2},\ x_{m_1},\ y_{m_1} -$$

coordinates of points M_5, M_4, M_3, M_2, M_1, M_0 which coincide with point M_6, but belong to links s_{65}, s_{54}, s_{43}, s_{32}, s_{21}, 0 (stand);

$$\varphi_{10},\ \varphi_{21},\ \varphi_{32},\ \varphi_{43},\ \varphi_{54},\ \varphi_{65}$$

are generalized coordinates. The trajectory of the grip motion is usually given with respect to stand 0 of the manipulator. In the coordinate form, the values of the coordinates of the point of grip $M_0(x\ y)$ with respect to the stand have the form

$$x_{m_6} = x_{m_1} \cos \varphi_{60} - y_{m_1} \sin \varphi_{60} + s_{65} \cos \varphi_{50} + s_{54} \cos \varphi_{40} +$$
$$+ s_{43} \cos \varphi_{30} + s_{32} \cos \varphi_{20} + s_{21} \cos \varphi_{10}, \quad y_{m_6} = x_{m_1} \sin \varphi_{60} +$$
$$+ y_{m_1} \cos \varphi_{60} + s_{65} \sin \varphi_{50} + s_{54} \sin \varphi_{40} + s_{43} \sin \varphi_{30} +$$
$$+ s_{32} \sin \varphi_{20} + s_{21} \sin \varphi_{10}. \qquad (25)$$

where

$$\varphi_{60} = \varphi_{65} + \varphi_{50}; \quad \varphi_{50} = \varphi_{54} + \varphi_{40}; \quad \varphi_{40} = \varphi_{43} + \varphi_{30}; \quad \varphi_{30} = \varphi_{32} + \varphi_{20}; \quad \varphi_{20} = \varphi_{21} + \varphi_{10}$$

are turning angles of AM links with respect to the stand.

Given $\varphi_{10} = \varphi_{10}(t)$ as the law of motion for link s_{21}, coordinates x_{m_1}, y_{m_1} may be calculated from equations 24f, then from equations (24) and (25) sequentially, the parameters are calculated

$$s_{21}, s_{32}, s_{43}, s_{54}, s_{65}$$

and coordinates x_{m_6}, y_{m_6} of point M_6. The values of angles

$$\theta_{21}, \theta_{32}, \theta_{43}, \theta_{54}, \theta_{65}$$

are determined based on relationships (23) or calculated analytically.

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USE OF BALANCED MANIPULATORS

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[Article by V. N. Danilevskiy, candidate of technical sciences, I. L. Vladov, engineer]

[Text] Until recently bridge cranes, hoists, winches, block and tackles, crane jibs and other equipment were basically used for mechanization of auxiliary tecnological operations on setting up intermediate products and removing finished products. These same means were used when repairing or servicing basic equipment for removing and setting up heavy units, replacing actuators, dies in presses, tools in metal-cutting machine tools, as well as for handling materials in warehouses.

These means are not very suitable to service technological operations with low machine time due to their technical-economic indicators.

Inconveniences in using traditional mechanized facilities are due to a number of causes. It is constantly necessary to monitor the product and suppress its tandency to swing. The necessity for precisely setting up the product makes it necessary to connect and disconnect the load-lifting device sequentially many times to obtain small movements. Frequently it is necessary to call a second operator or signalman to help. In the process of transferring and setting up the product there is a great probability of its hitting the equipment which frequently leads to breakage of expensive equipment and damage to the surface of the product. All this indicates that only a highly skilled operator can operate the traditional means for mechanizing auxiliary operations,that using these means to load the equipment requires considerable time and that these means are not efficient enough today to solve the problems of raising further the standard of production and the productivity of labor.

In recent years, in our country and abroad, a new class of machines -- balanced manipulators -- began to be widely used. Similar in their functions to materials handling equipment these devices link up closely with automatic manipulators. Convenience and simplicity of operation make it possible to use them to service the most diverse processes and make the labor considerably easier.

Balanced manipulators can be installed in only small areas and the basic equipment they service does not need additional work done on them; therefore, as a rule, they are easily inserted into existing production facilities without calling for reconstruction. These manipulators have a considerable load-lifting capacity and large servicing zones. When there is a new change in a product to be produced, it is only necessary to change the manipulator grip. Manipulator designs are fairly simple and reliable and do not need practically any very scarce components and materials. They are easy to repair and do not require highly skilled specialists for servicing and repairs. Specialization is not required in the manufacture of manipulators and they may be organized at practically any machine building plant.

The principle of operation of a balanced manipulator is that the load hung or held with the grip at the end of the actuator, is constantly balanced by a force developed by a vertical motion drive. This makes it possible to move the load manually in any direction in a horizontal plane while, in a number of manipulator models -- also in the vertical plane by applying a small force, needed to overcome friction in the bearings and supports of the actuator, in the drive and in the transfer mechanism. By moving and orienting the product with both hands, the operator can move it in narrow spaces, along a complicated trajectory, bypass an obstacle, stop it rapidly and smoothly and set up the product precisely in a given place without many cut-ins and cut-outs.

The balanced manipulator uses a simple pneumatic drive. The presence of a linear motion drive in the form of a pneumatic cylinder, the possibility of connecting the pneumatic cylinder directly to the actuator of the manipulator eliminates the necessity of using a transfer mechanism (reducer, motion converter) which reduces friction losses considerably when moving the product in the up and down direction. This makes it possible for the operator to lift a 100 kilogram product manually by applying a 4 to 5 kilogram-force. When the operator attempts to lift or lower a load, a change in the vertical movement pneumatic cylinder is a signal to the control system to open the cavity of the pneumatic cylinder and its connection to either the source of compressed air (lift) or to the atmosphere (lower). When the operator stops the action on the product, the balancing pressure in the pneumatic cylinder is restored and its cavity is closed.

Pneumatic balanced manipulators are used fairly widely. Their properties are used to the best advantage where there may be explosion or fire hazards. However, they also have some shortcomings. With the pressure variations in the shop pneumatic network which are frequently observed, their lifting capacity changes. Therefore, they should be designed not for standard air pressure, but for a somewhat lower one and the rated lifting capacity of the manipulator should be reduced accordingly. Otherwise it is necessary to provide an independent compressed air source. This solution may be found to be entirely acceptable by the simultaneous use of a group of manipulators in one or several adjacent sections of the shop.

Manipulators require a fairly thorough preparation of air, especially its drying. Special attention should be given to the safety of their operation. The design should include interlocking devices that keep the load from falling and insure the cutting out of the manipulator when the air pressure drops below a certain limit, and when the mains of the pneumatic system break.

The unsuitability of pneumatic manipulators when there are no pneumatic networks makes their introduction in a number of various industrial sectors considerably more difficult.

Balanced manipulators with electric drives have wider possibilities for use, but also have their special features. A transmission mechanism is required in the design to reduce the rotation speed of the electric motor shaft and convert the rotary motion to linear. This increases friction losses considerably and, when lifting the product manually, greater force is required than in pneumatic manipulators. For example, to lift a 100 kilogram load requires a 25 to 28 kilogram-force which, of course, is unacceptable. Therefore, in the design of manipulators with electric drives a control lever is provided which is located directly near the load. The lever is made so that the operator can conveniently use one hand (usually the right one) to hold and direct the product, while the other hand deflects the lever. The lever control is used only to move the product vertically and for continuous regulation of the speed whose value depends on the position of the lever. The possibility of obtaining low "creeping" speeds is provided. The range of change in the speed is usually selected within limits of 80 to 100.

Some manipulator designs use reversible electric motors while others use irreversible ones. In the first case, the technological possibilities of the manipulator are expanded: it can mechanize operations requiring vertical feeds, for example, brace and bit drilling, countersinking etc. In the second case, the load is lowered by gravity and the motor regulates only the speed of lowering. This simplifies the control system.

There are designs with electric motors whose control systems "remember" signals corresponding to current parameters for lifting and lowering loads, and for overcoming friction. Such designs are not widely used due to the complexity of control.

Balanced manipulators with hydraulic drives are of two types. The first type has the same load-lifting capacity as pneumatic and electric drive manipulators. An induction electric motor, in this case, turns a built-in pump in the design of the power unit. The working liquid is pumped into an accumulator that feeds the vertical movement drive. There is a complete similarity to manipulators with electric drives: the control lever, connected kinematically with the hydraulic distributor, is located on the loading unit near the product. The speed of vertical movement depends on the angle of lever deflection from the neutral -- horizontal -- position. The second manipulator type has considerably more load-lifting capacity of up to 1000 kilograms and more. Because these manipulators move considerable weights, the absolute values of friction forces when moving in the horizontal plane become large. It becomes necessary to install additional drives to move the load in the longitudinal direction and, frequently, for turning around the vertical axis. Control panels for such manipulators are detachable and they are hung on the loading unit when working with comparatively small size products in small zones, or they are held by hand when servicing large zones.

The great diversity of operations when servicing various technological processes, mechanized by balanced manipulators, makes it necessary to create a wide range of models that differ in arrangements, types of drives, volumes of servicing zones and load-lifting capacities.

Of the most widely used manipulators (over 95% of the total) equipped only with a vertical movement drive, the following basic units and assemblies may be identified: base, a head mounted on it which can be turned around the vertical axis and an actuator -- an arm with a loading unit at the end, a drive and a control system. The drive is mounted on the head while the control lever is mounted on the loading unit directly near the load which makes operating it more convenient for the operator.

The manipulator arrangement is determined by the size of the production room, the volume of the servicing zone, by the section layout and, in some cases, by the special features of the technological process being mechanized. Typical designs of manipulators are: stationary -- floor type, mounted on a column with a cantilever installed on a wall, ceiling or directly on the equipment; suspended, base mounted on a cart, moving over a monorail or two or three rails, which may be fastened to a wall, ceiling or a special platform; transportable (on a cart without a drive) and self-propelled (on a small truck).

The observance of the modular-unit principle makes it possible to achieve a high level of standardization, while in manipulators of equal load-lifting capacities, servicing similar working zones and equipped with the same types of drives, all units -- head, drive, actuator, loading unit -- may be completely equal independent of the arrangement.

MP-100-2, MP-100-8 and MP-100-3P balanced modulators with lifting capacities of 100 kilograms differ considerably in their technical characteristics. The length of the working zone of the MP-100-8 suspended manipulator on a platform exceeds 40 meters; of the two others -- stationary mounted on a column -- it is a 25x1.6 meter rectangle. The MP-100-3P manipulator is explosion- and fireproof, and has a pneumatic drive and a pneumatic control system; two others are equipped with electromechanical drives. Nevertheless, the degree of standardization achieved in these designs is very high. The columns are the same in both stationary models, as well as the drives and control systems in electromechanical manipulators; the leverage linkage of the actuators do not differ in any way and the loading units are similar. The design of the turning for fastening the head to the base makes it possible to use the same head for all three manipulator models and the finishing work involves only the kinematic connection between the vertical movement cart and the drive.

Balanced manipulators are most successfully used in servicing machining processes of fairly heavy metal parts. In this case, we are talking not so much about eliminating production workers as about eliminating heavy manual labor and raising the productivity of labor and the standard of production.

The use of the MP-100-3 manipulator has made a considerable change in the organization of production of ring intermediate products weighing about 100 kilograms. In previous technology, a two-shift stock in slings was delivered to the section by an overhead crane and dumped at the turning and boring lathe, occupying an area of several dozens of square meters. Some 24 intermediate products were machined during the shift and they were set up on the machine tool by a hoist, which required placing each intermediate product into a sling, moving it to the machine tool, lowering it to the table and freeing it from the sling.

In doing these operations, it is difficult to observe safety technique requirements, especially in setting up the intermediate product on the table because its supporting surface is seldom positioned properly in the horizontal plane and, after touching the table, it is necessary to place it in the proper position by cutting the hoist in and out many times. After the machining is completed, the finished part is also laid in a random position on a free area by the hoist. To remove finished products from the area with an overhead crane required the slinging of a pile of parts.

After installing the MP-100-3 manipulator, equipped with a three-finger grip which makes it possible to grab the ring from the inside, intermediate and finished products are placed in stacks on special trays not over 2 meters from the manipulator. Each stack contains 15 to 20 rings.

Over ten such stacks can be placed near the manipulator, i.e., a four-five work shift stock can be created which would facilitate the regularity of the work.

Setting up and removing intermediate products and parts is done in the following sequence. The loading unit with the grip is brought to the stack of intermediate products and the grip is inserted in the upper intermediate product. When the flywheel of the grip is rotated, its fingers spread out and press against the inner channel of the ring and grasp the intermediate product firmly. A turn of the control lever on the loading unit raises the intermediate product above the stack, carries it to the machine tool and lowers it to the table. A turn of the flywheel of the grip in the opposite direction frees the intermediate product. Continuous regulation of the speed of the vertical travel of the loading unit and the constant orientation of the intermediate product in the horizontal plane make it possible to bring the grip to the stack smoothly and lower the intermediate product accurately and gently on to the machine tool table providing full safety of work when loading the equipment. The simplicity of this operation makes it possible for the worker to assimilate it very rapidly. After machining the intermediate product the finished part is gripped, carried and placed in stacks of finished products in a similar manner. As they accumulate, the stacks, along with the trays, are removed by the overhead crane.

Thus, the use of the balanced manipulator increased safety and the standard of production, reduced the required section area, and made it possible to eliminate the use of a hoist and reduced the usage time of an overhead crane. Labor-consuming auxiliary operations for loading and unloading equipment and operations related to handling intermediate and finished products were reduced by half, and reduced labor for manufacturing a unit product by 10%.

The use of the MP-100-8 overhead balanced manipulator at a section for machining about 100 kilogram cylindrical parts has a significant technical-economic effect. The gantry type of manipulator consists of a monorail mounted on a platform along which two carts travel independently. On each of the carts there is mounted a head with an actuator that carries the loading unit with a self-clamping grip. The cart has a dc motor with a worm reducer. It travels along a cable attached to it at the ends of the monorail with a pulley at the output shaft of the reducer.

Parts are delivered sequentially on carts to the section which has 12 machine tools with ChPU [Numerical Programed Control]. The use of the manipulator makes it possible to eliminate an overhead crane which had previously transferred parts operation by operation. The process itself of placing and removing parts on and from the machine tool was simplified considerably. The self-clamping grip and the continuous regulation of the speed of vertical travel provide reliable fixing of the part, its smooth removal and installation, as well as the possibility of accurate, shockless moving of the part to the cams of the machine tool fixtures for which slings and braces were used previously. The rigid grip installation on the loading unit fully eliminates the swinging of a long part which also increases work safety and reduces the possibility of the part hitting machine tool components. Auxiliary operations time is reduced to a third.

The use of the manipulator increased the level of mechanization, eliminated one production worker, increased the productivity of labor and the loading coefficient of the basic equipment, improved working conditions and practically eliminated scrap as a result of damaging the surface of parts and of striking the equipment.

The economic effectiveness of introducing the MP-100-8 manipulator was 10,000 rubles per year with a two-shift work schedule.

MP-100-8 technical characteristics

Load-lifting capacity, kilograms	100
Servicing zone volume, meters	42x4.6x1.2
Turning angle of the head around the vertical axis, degrees	200
Highest vertical travel speed of loading unit, mm/sec	250
Longitudinal travel speed of the cart, mm/sec	500
Three-phase electric power voltage, volts	380
Power consumption, kw	1.0

Balanced manipulators are being introduced successfully not only in mechanizing machining processes. They are also used effectively to mechanize the processes of plating, making casting molds, painting, materials handling in warehouses and servicing conveyors, and other technological processes involving heavy and monotonous manual labor. They may also be used for basic technological operations. A drill, a polishing disk, a device for cleaning surfaces and tongs for precision welding can be installed on the loading unit. The use of balanced manipulators is very prominsing for mechanizing materials handling work at comprehensively automated lines.

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STANDARDIZATION OF LINEAR MANIPULATOR MODULES ACCORDING TO DESIGN PARAMETERS

Moscow MEKHANIZATSIYA I AVTOMATIZATSIYA PROIZVODSTVA in Russian No 9, Oct 82, p 25

[Article by I. I. Pavlenko and A. A. Panov, candidates of technical sciences]

[Text] The modulator design of automatic modulators (AM) is being used more and more widely because this makes it possible to create (assemble) an AM of the necessary complexity, with the required characteristics, considerably faster. This eliminates the need for excess functional possibilities in the AM, related to an increase in their cost, or the impossibility of using individual non-modular AM in view of the inadequacy of their characteristics. In the modular form of design, the mechanical part of the AM will represent a set of functional mechanisms that provide necessary advancing, rotational, gripping and other movements which are made possible by a certain number of standardized modules with various technical characteristics that permit assembling them in any desired combination.

The existing diversity of designs of linear movement AM can be reduced to several forms (Fig. 1). The most widely used are linear drives in the form of pneumatic and hydraulic cylinders in which the moving link is a rod (see Fig. 1a) or, in individual cases, the cylinder itself (see Fig. 1d). To increase the rigidity and accuracy of the drive, to eliminate the turning of the moving link around its own axis, to regulate the link movement or to transmit movement to the following drives, one or several additional links are placed in some AM in parallel with the movable link (see Fig. 1c). Movable links in linear drives are also made in the form of bars (see Fig. 1e) actuated by rack and pinion, worm gear and other drives.

The provision of basic technical characteristics must be the basis of establishing the gradation of linear AM modules. Of these, the primary ones are: travel distance; loading capacity; travel speed of the movable link; positioning accuracy and other characteristics.

The value, as well as the speed of mobile link travel, must be selected in correspondence with the values of the basic R5 series or the additional R10 series.

The loading capacity of the modules depends on the load-lifting capacity of the AM whose gradation according to this parameter must represent a geometrical series with a denominator equal to 1.6.

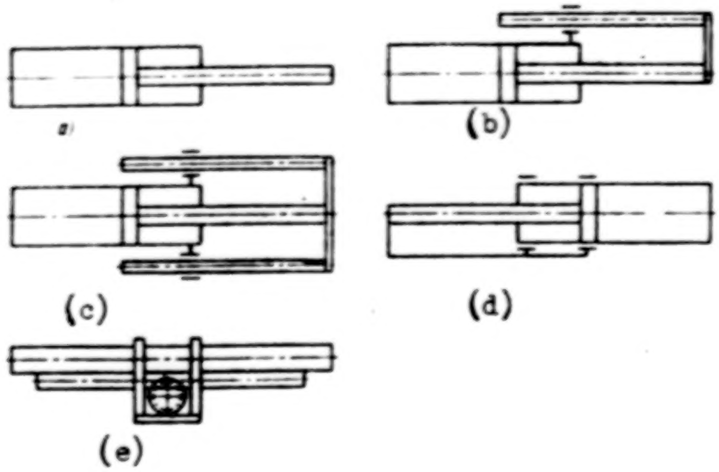

Fig. 1. Types of linear AM drives

In coordinating the load capacity of the modules and the load-lifting capacity, it is necessary to proceed on the basis of the most unfavorable conditions of their operation when they provide vertical travel and absorb the weight of the load being lifted and other loads directly. Thus, for cylindrical modules, two variations are possible, i.e., the upward travel is provided by feeding the working medium (liquid or air) into the rodless or rod cavity. When feeding the working medium into the rodless cavity, the area of the module cylinder will be equal to

$$F = \frac{P + G}{p} = \frac{P\ (1 + k)}{p}\ ,$$

where P -- load-lifting capacity of the AM; G -- weight lifted by the module of the AM design and other additional loads (friction etc); p -- unit pressure of working medium; k -- G/p. Cylinder diameter D is determined from equation

$$D = \sqrt{\frac{4\,P\ (1 + k)}{\pi\, p}}\ .$$

For the second variation

$$D = \frac{4\,P\ (1 + k)}{\pi\, p\ (1 - c^2)}\ .$$

where c=d/D; d -- diameter of rod.

An analysis of the obtained formulas indicate that changing from one load-lifting capacity P_1 to another $P_2 = P_1 \varphi$ (where φ =1.6) leads to changing the cylinder

diameter by 1.25 times. Thereby, the indeterminacy of changing the weight lifted by the module of the AM design and other loads G makes it possible to recommend the rounding out of their values with a reserve to the necessary accuracy so that, when taking into account all loads acting on the module, a value in the R10 series with a denominator equal to 1.25 can be used. This assumption may be fully justified because a more fractional gradation of these loads and, therefore, of diameters is hardly expedient. The gradation of the dimensions of the diameter according to series R5 should be considered as the basic one while the gradation according to R10 as a supplementary one. On this basis, it is possible to represent the gradation of linear modules according to the diameter of the mobile links and the value of their travel. Thus, the parameters of linear AM modules according to the basic R5 series are shown in Table 1.

Table 1

Diameter of mobile link of module d (mm)	10	16	25	40	63	100	160
Travel of mobile link of module 1, mm	10	10	10	10	10	10	10
	16	16	16	16	16	16	16
	25	25	25	25	25	25	25
	40	40	40	40	40	40	40
	63	63	63	63	63	63	63
	100	100	100	100	100	100	100
	160	160	160	160	160	160	160
		250	250	250	250	250	250
			400	400	400	400	400
				630	630	630	630
					1000	1000	1000
						1600	1600
							2500

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